COMPUTER SIMULATION FOR
THE LAYOUT OF A POINT-TO-POINT RADIO SYSTEM

by

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MAJOR TECHNICAL REPORT

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RADIO COMMUNICATIONS

AND

POWER UTILITIES REQUIREMENTS

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ABSTRACT

This report presents a design procedure of Point-to-point Radio Communication System operating in the VHF, UHF, and microwave bands. Chapter 1 summarizes the accomplished work in the form of introduction. The necessary material for introducing the reader to the subject is included in Chapter 2. In the nine sections of this Chapter, Point-to-point Radio System, Radio Path and Inverse Position Azimuth, Curvature and Earth Radius Factor, Free Space Loss, Fresnel Zone Radii, Clearance Criteria, Propagation Reliability and Diversity Consideration, Necessary Bandwidth, and Weighted Circuits are discussed. Chapter 3 describes the Power Utilities Communication Requirements. Chapter 4 presents the Design Procedures of Point-to-point Radio Communication System using a developed set of programs. Finally Chapter 5 presents the Conclusion of this study, by summarizing the advantages and disadvantages of using the proposed scheme, recommended levels of system performance, and the future of Point-to-point radio communication to the Power Utilities.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

A = Free space propagation attenuation.

AZIM = Program AZIM for azimuth and distance calcuations.

B.B.I. = Baseband improvement factor.

B.W. = Bandwidth.

C = Received signal input to the receiver.

CLEAR = Program CLEAR for path clearance calculations.

D = Distance

dB = Decibel; one-tenth of a bel, the number of decibels denoting the ratio of the two amounts of power being ten times the logarithm of the base 10 of this ratio.

dBa0 = Decibels of adjusted noise-interference power referred to 0dBm at the reference-transmission level point. Used for interference noise measurements with Bell F1A-HAI telephone sets and with the reference noise power at - 85 dBm at 1000 cps (F1A-weighting).

dBm = Decibel above one milliwatt.

dBm0 = Decibels of sinusoidal signal, or noise, power referred to 0 dBm at reference-transmission-level point.

dBmOp = An interfering sinusoidal or noise power level in a telephone system measured with a CCITT standard telephone psophometer and giving the same reading as an 800-cps tone of equal power level in dBm0.

dBrnco = Decibels above reference noise, adjusted for C-message circuits used for interference-noise measurements with Bell 500 telephone sets and with reference noise power at - 90 dBm at 1000 cps.

dBw = Decibel above one watt.

F = Frequency.

F1 = First Fresnel zone radius.

FDM = Frequency duration modulation.

FM = Frequency modulation.

FMFA = Frequency modulation factor.

K = Earth factor.

P.E. = Pre-emphasis.

P.T.P.R.S. = Program P.T.P.R.S. for Point-to-point radio system performance calculations.

pWpO = Picowatts (10^{-12} watt) interference noise level measured psophometrically by relating the psophometric emf to equivalent output power in a 600-ohm matched system.

Psophometric emf = 2 x (psophometric voltage) for 600-ohm resistive circuit. Psophometric voltage: interference noise voltage present at a measuring point in a telephone system, measured as recommeded by CCITT using a psophometer (noise voltage meter).

I = Diversity improvement factor.

I_{fd} = Frequency diversity improvement factor.

I_{sd} = Space diversity improvement factor.

I.F. = Intermediate frequency.

R.F. = Radio frequency.

R.M.S. = Root mean square value.

S/N = Signal to noise ratio.

T.N. = Total noise.

U = Rayleigh Un-availability.

U_a = Actual Un-availability.

U.H.F. = Ultra high frequency (300 - 3000 MHz).

V.H.F. = Very high frequency (30 - 300 MHz).

CHAPTER 1

INTRODUCTION

The objective of this study is to develop an effective method of technical Engineering design procedures to study the feasibility of a Point-to-point radio system. Three computer programs were developed to perform all the necessary calculations and to provide the designer with a complete picture for the expected system performance. Their use is proposed within a specific scheme as outlined in Chapter 4. This scheme provides the designer with several alternatives to obtain the best performance.

CHAPTER 2

BACKGROUND

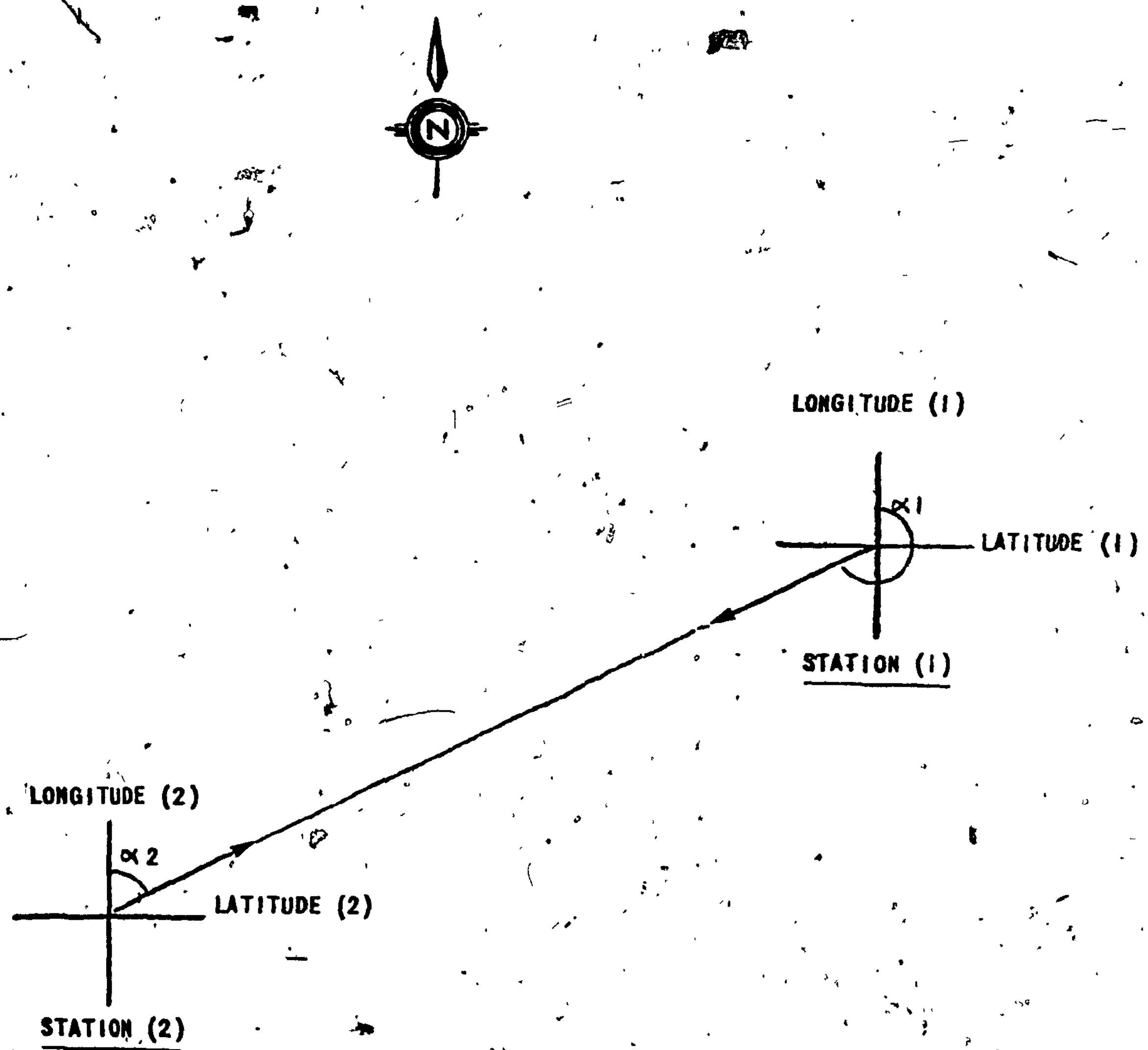
2.1 Point-to-point Radio System:

Radio transmission is defined as the transmission of signals by means of radiated electromagnetic waves other than light or heat waves. Point-to-point Radio System is defined as radio transmission between two fixed points (sites). A basic characteristic of electromagetic energy is that it travels in a direction perpendicular to the plane of constant phase; i.e. if the beam were instantaneously cut at right angle to the direction of travel, a plane of uniform phase would result. If, on the other hand, the beam entered a medium of non-uniform density and the lower portion of the beam traveled through the more dense portion of the medium, its velocity would be less than that of the upper portion of the beam. The plane of uniform phase would then change, and the beam would bend downward. This is refraction, just as a light beam is refracted when it moves through a prism. As a matter of fact, most of the characteristics of radio beams can be visually demonstrated with light waves, and in a very small space. The atmosphere surrounding the earth has the non-uniform characteristics of temperature, pressure and relative humidity, which are the parameters that determines the dielectric constant, and therefore the velocity of propagation. The earth atmosphere is therefore the refracting medium that tends to make the radio horizon appear closer or farther away. It also effects the path clearances in the manner discussed in Section 2.5.

2.2 Radio Path and Inverse Position Azimuth:

The radio path is the straight line route that links the two sites of a Point-to-point radio system together. A path profile study is a plot showing the terrain criteria over the path. Then the radio beam clearance everywhere at different "K" values could be examined (this is discussed in Section 2.3).

Inverse Position Azimuth is the angle by which each site's antenna should be pointed towards the other site. It is measured in angles East of true North. Program "AZIM" shown in Appendix A computes the distance between any two sites, and the inverse position azimuth. Figure 2.2 sketches the inverse position azimuth between two sites.



α 1 ANGLE OF AZIMUTH AT STATION (1) TOWARDS STATION (2)

α 2 ANGLE OF AZIMUTH AT STATION (2) TOWARDS STATION (1)

FIG. 2.2 INVERSE POSITION AZIMUTH

2.3 Curvature and Earth Radius Factor "K":

The relative curvature of the earth and the radio beam is an important factor when plotting a profile chart. Although the surface of the earth is curved, a beam of microwave energy tends to travel in straight line. However, the beam is normally bent downwards a slight amount by atmospheric refraction. The amount of bending varies with atmospheric conditions. The degree and direction of bending can be conveniently defined by an equivalent earth radius factor "K". This factor "K" multiplied by the actual earth radius "R", is the radius of a fictitious earth curve. The curve is equivalent to the relative curvature of the radio beam with respect to the curvature of the earth; that is, it is equal to the curvature of the actual earth minus the curvature of the actual beam of radio energy. Any change in the amount of beam bending caused by atmospheric conditions can then be expressed as a change in "K". Existing maps showing the variation of "K" value over a complete year period should be examined for the particular region under study.

In all cases, it is of interest to study the path under normal atmospheric conditions when "K" is equal to 4/3. Accurate results can be obtained only when the value of "K" is stable. This can be expected over most terrain only during fair weather and in the daytime hours at least 1 to 2 hours after sunrise and before sunset. The factor "K" is presented by the following formula [3]:

$$K = \frac{1}{1 + \frac{a}{2}\,\frac{\Delta\varepsilon}{\Delta h}}$$

where a is the radius of the earth.

$\Delta\varepsilon$ is the change in the atmosphere dielectric constant in going from height h to h + Δh.

Program CLEAR outlined in Appendix B computes the radio beam clearance at K values of 2/3, 1, 4/3, and infinity.

2.4 Free Space Loss

Free space loss is defined as the loss that would be obtained between two isotropic antennae in free space, where there are no ground influences or obstructions; in other words, where blocking, refraction, diffraction and absorption do not exist. An isotropic antenna is defined as one which radiates or receives energy uniformly in all directions. Although such an antena is physically unrealisable, it provides a convenient reference point for calculations. The Free space loss increases with both distance and frequency and the formula used is [1]:

$$A = 96.6 + 20 \log_{10} F + 20 \log_{10} D$$

where A = Free space attenuation between isotropic antenna, in dB.

F = Frequency in GHz.

D = Path distance, in miles.

The developed program P.T.P.R.S. outlined in Appendix (C) includes this formula. The actual nature of losses in Free space are basically due to the fact that radio energy is lost in space primarily because of the spreading of energy in the wavefront as it travels through space, in accordance with the inverse-square law. Only a small amount of the energy which is radiated from the transmitting antenna actually reaches the receiving antenna. The remainder is spread over areas of the wavefront outside the capture area of the receiving antenna (See Fig. 2.4 for a Typical Radio System Gains and Losses).

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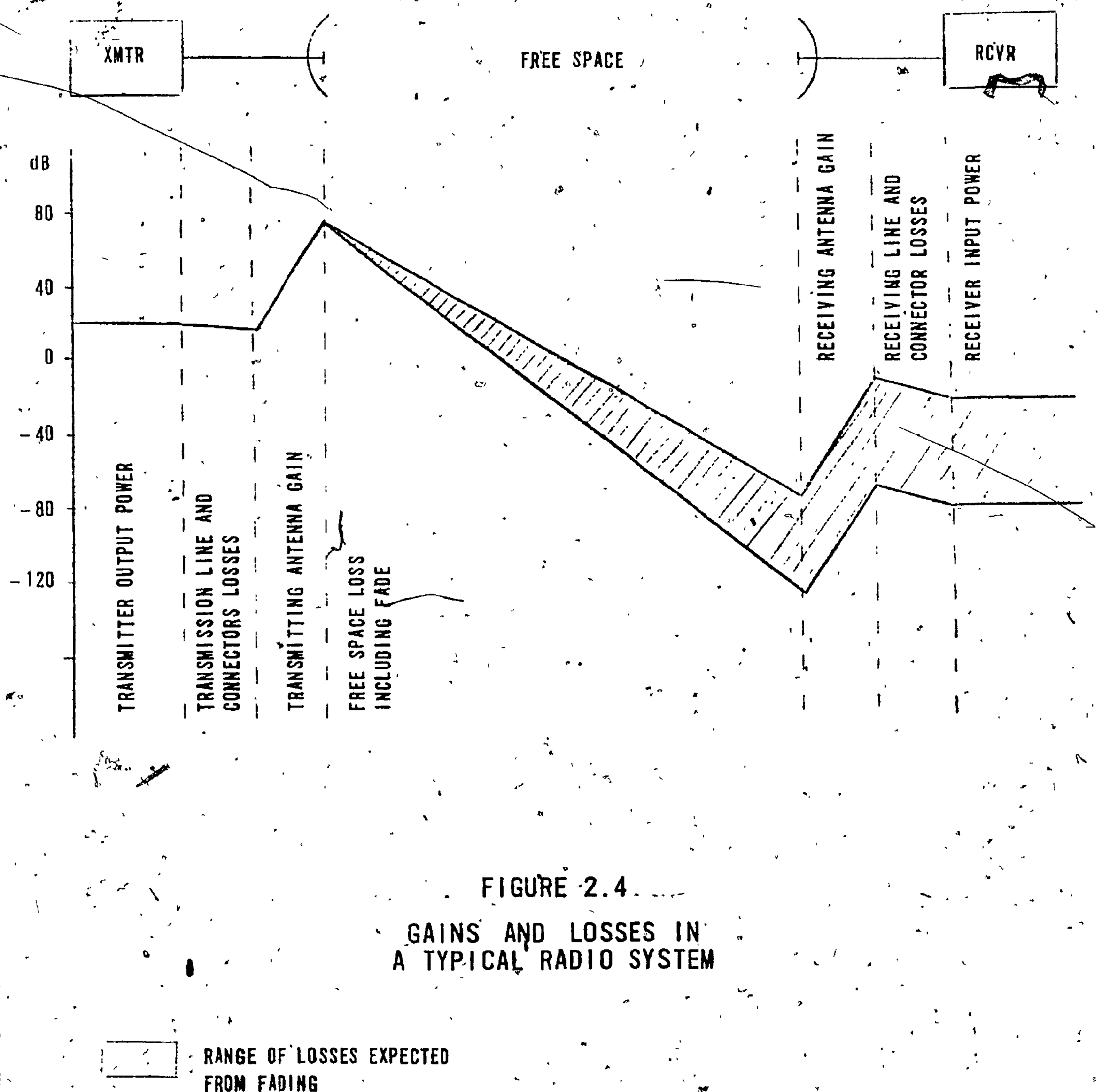

FIGURE 2.4

GAINS AND LOSSES IN A TYPICAL RADIO SYSTEM

2.5 Fresnel Zone Radii:

Radio beams travel in straight lines as they are radiated from the transmitting antenna and are received at the far end by a receiving antenna. There is a straight beam that connects the centres of both antennae, while, other beams radiate towards the earth and then are reflected towards the receiving antenna. If the direct signal from the transmitting to the receiving antenna, and the groundreflected energy are in phase addition at the receiving antenna, a peak above free space loss occurs. The amount of phase difference between the direct beam and the reflected beam is represented by the amount of clearance at any possible reflecting point. The first Fresnel zone radius is a kind of "rubber" unit, which is used to measure certain distances (path clearance in particular) in terms of their effect at the frequency in question, rather than in terms of feet. In order to ensure free space propagation it is essential that all potential obstructions along a path are removed from the beam center-line by at least 0.6 F1, where F1 is the radius of the first Fresnel zone at the point of the obstruction on possible reflection. The developed program "CLEAR" shown in Appendix B, computes the value of F1, and compares it to the computed clearance at 0.5 miles intervals of the radio path. This is repeated for "K" values of 2/3, 1, 4/3, and infinity and the calculations are made for any frequency band in question. The first Fresnel zone at any point in the path may be calculated from the following formula [1]:

$$F1 = 72.1 \sqrt{\frac{d1 \times d2}{fD}}$$

where $F1$ = first Fresnel zone radius, in feet

$d1$ = distance from one end of path to reflection point in miles.

D = total length of path in miles.

$d2 = D - d1$

f = Frequency in GHz.

The Fresnel zone number $Fn = F1 \sqrt{n}$ (See Fig. 2.5).

2.6 Clearance Criteria:

The following are the recommended minimum required clearances for radio paths:

(a) For systems with high reliability requirements; at least 0.3 F1 at K = 2/3 and, 1.0F1 at K = 4/3, whichever is greater. In areas of very difficult propagation, it may be necessary also to ensure a clearance at least grazing at K = 1/2 [1].

(b) For systems with slightly less stringent reliability requirements; at least 0.6F1 + 10 Feet at K = 1.0. At points quite near the ends of the path, the Fresnel zones and earth bulge become vanishingly small, but it is still necessary to maintain some minimum of perhaps 15 to 20 feet above all obstacles [1].

2.7 Propagation Reliability and Diversity Consideration:

As shown earlier radio propagation is a function of atmospheric conditions which at any rate cannot be totally predicted. Reliability, the measure of consistent character or quality, is represented in Point-to-point Radio propagation by the continuous presence of effective received

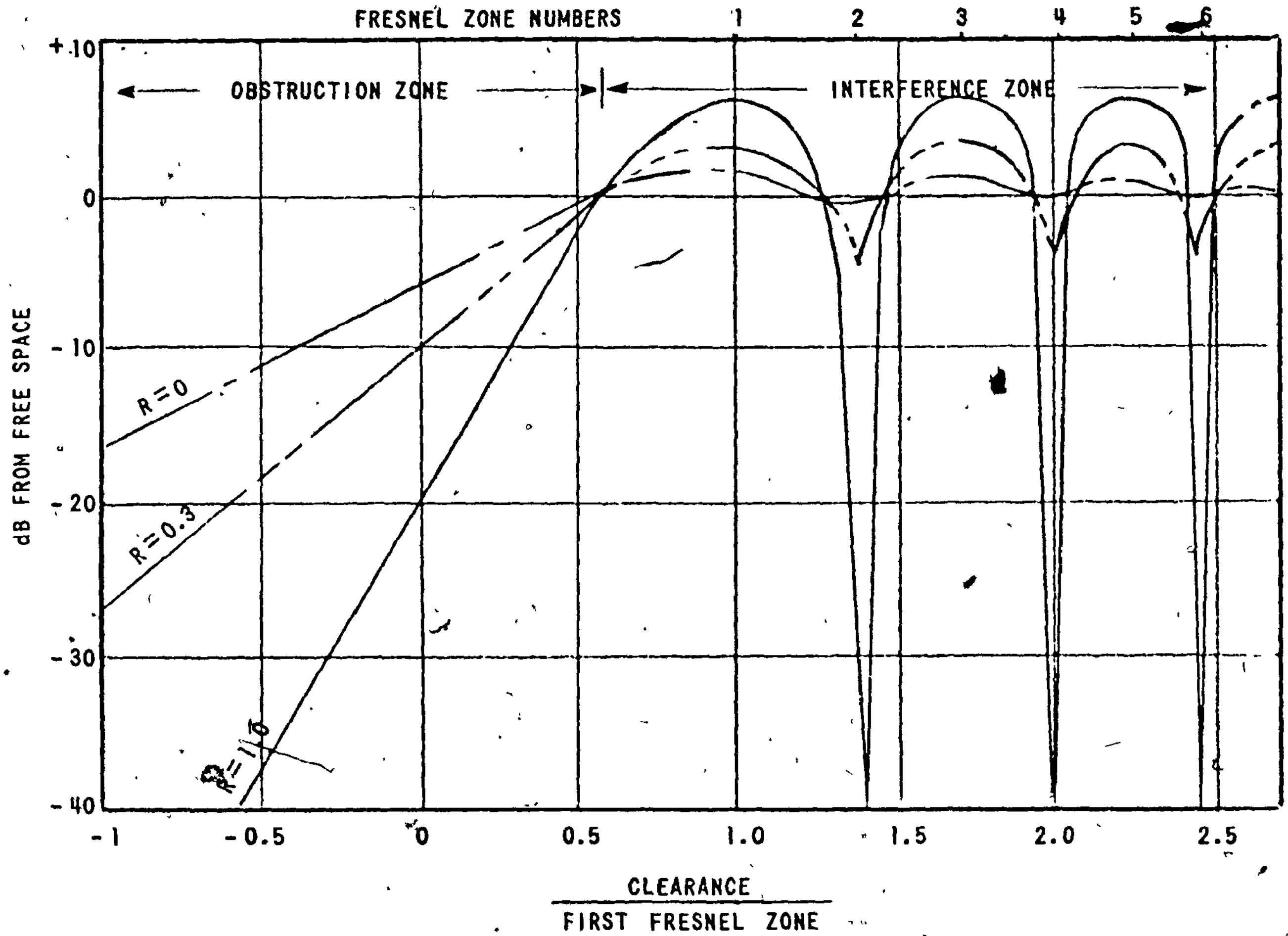

FIG. 2.5

BEHAVIOR OF ATTENUATION vs PATH CLEARANCE FOR VARIOUS TYPES OF OBSTRUCTION

R = REFLECTION COEFFICIENT

signal. The most famous measurements made by W.T. Barnett [8] introduced important factors in considering diversity systems. The amount of fade margin available in the system is not the only factor used to represent unavailability of the circuit. The well-known Rayleigh (fading) probability density function is given by

$$U = 10^{-F/10}$$

where F = Fade margin (dB) has to be corrected as follows:

(i) <u>Non-diversity System:</u>

$$U_a = a \times b \times 6.0 \times f \times (D)^3 \times 10^{-F/10} \times 10^{-7}$$ (See [1], [2])

where a = roughness factor = 4 for very smooth terrain

= 1 for average terrain with some roughness

= 1/4 mountaineous or very dry terrain

b = factor to convert work month probability to annual probability

= 1/2 for great lakes or similar humid areas

= 1/4 for average inland

= 1/8 for mountaineous or very dry terrain

f = frequency in GHz

d = path length in km.

(ii) <u>Diversity Improvement Factor</u>

Method of calculating the propagation reliability with diversity is to calculate separately the non-diversity outage of each one-way path and then a diversity improvement factor for each one-way path, as follows:

$$DIV = \frac{Ua}{I}$$

where DIV - Diversity

U_a = Probability of annual fading outages (non-diversity)

I = Diversity improvement factor.

a) Frequency Diversity Improvement Factor [2].

890-960 MHz Band	$I_{fd} = 3 \times \frac{\Delta f}{f} \times 10^{F/10}$
2 GHz Band	$I_{fd} = 1 \times \frac{\Delta f}{f} \times 10^{F/10}$
4 GHz Band	$= 1/2 \times \frac{\Delta f}{f} \times 10^{F/10}$
6 GHz Band	$= 1/4 \times \frac{\Delta f}{f} \times 10^{F/10}$
7 & 8 GHz Band	$= 1/8 \times \frac{\Delta f}{f} \times 10^{F/10}$
11 & 12 GHz Band	$= 1/12 \times \frac{\Delta f}{f} \times 10^{F/10}$

where I_{fd} = Frequency diversity improvement factor

f = Frequency diversity in GHz

Δf = Diversity spacing

F = Fade margin in dB.

b) Space Diversity Improvement Factor [2].

$$I_{sd} = \frac{1.2 \times 10^{-3} \times f \times S^2 \times 10^{\overline{F}/10}}{D}$$

where I_{sd} = space diversity improvement factor

S = vertical antenna spacing in meters

D = path length in km

$\overline{F}$ = fade margin associated with the second antenna. The $\overline{F}$ will cover the situation where the fade margins are different on the upper and lower paths. In such a case $\overline{F}$ will be taken as the larger of the two fade margins and will be used in calculating U_a for the path. $\overline{F}$ will be used in the calculation of I_{sd}

f = Frequency in GHz

c) Hybrid Diversity Improvement Factor [2].

Hybrid = I_{sd} ; Hybrid diversity is space and frequency diversity together.

The improvement factor is calculated as if the path were straight space diversity.

2.8 Necessary Bandwidth

The Necessary Bandwidth is the Radio frequency spectrum required for the R.F. carrier to deviate within. In FM/FDM systems this band is limited by the following factors:

- Peak Deviation; D
- Top baseband frequency; M

The Department of Communication Radio Standard Procedure RSP-113 provide formula for the computation of the Necessary Bandwidth [2].

$$B.W. = 2\,M + 2\,KD$$

where K is a constant between 0.9 and 1.0.

$$D = \text{R.M.S per channel deviation X "Factor"}$$

The above "Factor" to calcualte D is a function that expresses the noise loading ratio; it is the dB ratio between the r.m.s power of a white noise load whose peaks are equal to the peak values of the complex baseband signal during the busy hour, and the r.m.s power of a test tone of "0" dBm0 [7]. The peak value of white noise power is a statistical parameter with no specific value, but is commonly taken as 13 dB above the r.m.s power. However, this value varies and is somewhat higher for systems with fewer channels.

Since deviation in an FM system has the dimension of voltage, the effect of changes in deviation can be calculated as 20 $\log_{10}$ function of changes in load power. Program P.T.P.R.S includes all different formulae according to the number of voice channels in the system and as defined in RSP-113 [2].

2.9 Weighted Circuits:

It is the practice in telecommunication fields that voice circuits would be evaluated in their quality by special units. The weighted circuit is the quality of the voice channel circuit in relative noise values compared to the human ear hearings at 1000 Hz tone. Different standard values exist, the most common are the following [1]:

$$\text{dBrnc0} = -C - 48.1 + F - 20 \log_{10} \Delta f/_{fch}$$

$$\text{dBa0} = -C - 54.1 + F - 20 \log_{10} \Delta f/_{fch}$$

$$\text{pWpo} = \log 10^{-1} \left[\frac{-C - 48.6 + F - 20 \log_{10} \frac{\Delta f}{fch}}{10} \right]$$

where C = RF input power in dBm

F = Receiver noise figure in dB

Δf = Peak deviation of the channel for a signal of test tone level.

fch = Center frequency occupied by the channel in the baseband.

The relation between these values is as follows [1]:

$$\begin{aligned} \text{dBrnc0} &= 10 \log_{10} \text{pWpo} \\ &= \text{dBa0} + 6 \\ &= \text{dBm0p} + 90 \\ &= 88 - S/N \end{aligned}$$

where S/N is the signal to noise ratio (flat in dB).

The developed program, P.T.P.R.S computes this value first and then derives the other values according to the above; see Appendix C.

And, $S/N = RS - TN + BBI + FMFA + PE$

where,

RS = Received signal in dBm

TN = Total noise

BBI = Base band improvement factor

FMFA = F.M. Factor

PE = Pre-emphasis factor = 3.7 [1].

Total Noise (TN) = Receiver Noise figure + Noise in I.F. bandwidth + Antenna Noise + 10 dB (F.M. improvement factor).

Receiver Noise figure = Published by manufacturer (dB)

Noise in I.F. bandwidth = $10 \log_{10}$ (I.F. Bandwidth in MHz)

Antenna Noise at 290° K or,

the Receiver front end = - 114 dBm per MHz of bandwidth [1].

(The FM improvement threshold or the FM breaking point, occurs when the power of the signal is approximately 10 dB higher than the noise. At this point the peaks of the signal begin to exceed the peaks of the noise and FM quieting begins. For input signals higher than this level, the thermal noise in a derived channel will decrease 1 dB for 1 dB increase in RF input level. If the input signal drops below the FM threshold, the noise in the derived channel rises quickly to an intolerable level. Consequently, most receivers are arranged to squelch when the level drops below this point. The maximum available fade margin in such receivers is, therefore, the difference in dB between the normal unfaded signal and the FM improvement threshold).

Hence,

TN, in dB = 104 + 10 $\log_{10}$ (I.F. B.W. in MHz) + Receiver Noise figure in dB

$$FMFA = 20 \log_{10} \frac{\text{Peak Deviation } (= \text{R.M.S dev.} \times \sqrt{2})}{\text{Baseband in MHz}}$$

$$BBI = 10 \log_{10} \frac{\text{I.F. bandwidth in kHz}}{2 \times (\text{voice Ch.} = 3.1 \text{ kHz})}$$

CHAPTER 3

POWER UTILITIES COMMUNICATION REQUIREMENTS

Power Utilities provide an essential service to customers at locations dispersed over wide areas. Many miles of transmission lines are used to interconnect the customer loads and the generating stations, some of which may be quite remote from their loads. Reliable communications are a basic necessity for the operation and administration of such systems. The main independent communication system used by power utilities are as follows [11]:

1. The protection Relaying Communication Facilities.
2. The supervisory control systems.
3. The Data Aquisition and Control system.
4. The Power system operating voice circuits.
5. The Administration voice Network.
6. The Mobile radio system.
7. The Data Processing communication system.

All of the above communication systems are being used to provide and administer a reliable and economical supply of power throughout the area served. The importance of these facilities becomes apparent when a power disturbance occurs. Under such a condition, the troubled area could be quickly monitored and dealt with to prevent successive trouble build-up in the system.

The above systems could be served by different types of communication circuits. Power Line Carrier communication system is one of the most popular systems for Power Utilities. However, the limited capacity of voice circuits, and the possible loss of signal under fault conditions on the same lines limits its capability. Renting circuits from common carrier faces the problem of bringing telephone cables normally to high voltage compounds. This requires expensive protective devices (i.e. neutralizing transformer costing about $30,000 each, and isolating transformers) to protect the lines from ground potential rise (could go up to 13,000 volt) under power system fault.

Coaxial cable systems are not used normally by Power Utilities. Their high costs are justified for very large capacity users only (e.g. Telephone companies). Fibre-optics is a new potential in communication circuits for power Utilities, where complete isolation (ground potential rise problems) could be achieved. Attenuation per distance length has been reduced to an attractive figure without the need to use new connections. However, trouble free terminal equipment service is still doubtful.

The Radio-Frequency Communications remain highly attractive. Terminals are privately-owned and located at the site directly. Complete isolation is obtained where separate power supplies are normally used. However, the problem of "Spectrum Management" and restricted licensing regulations which makes their use difficult, still persists.

CHAPTER 4

POINT-TO-POINT RADIO SYSTEM DESIGN PROCEDURE

Preliminary facility planning (including operational requirements as described in Section 2.0, traffic studies, expansion potential, reliability requirements, and cost studies) has to be completed to such a degree that the points to be served have been fixed, and the required system capacity has been determined. Once sites have been chosen as accessible and could be provided with power supply, the developed programs shown in Appendices, could be used. The flow chart outlined in Fig. 4.1 illustrates the use of these programs.

It should be noted that the designer has to select several frequency bands to examine the path clearance (see Appendix B - Program CLEAR). Also, once a band has been chosen, equipment data should be investigated according to the information published by manufacturers in this field.

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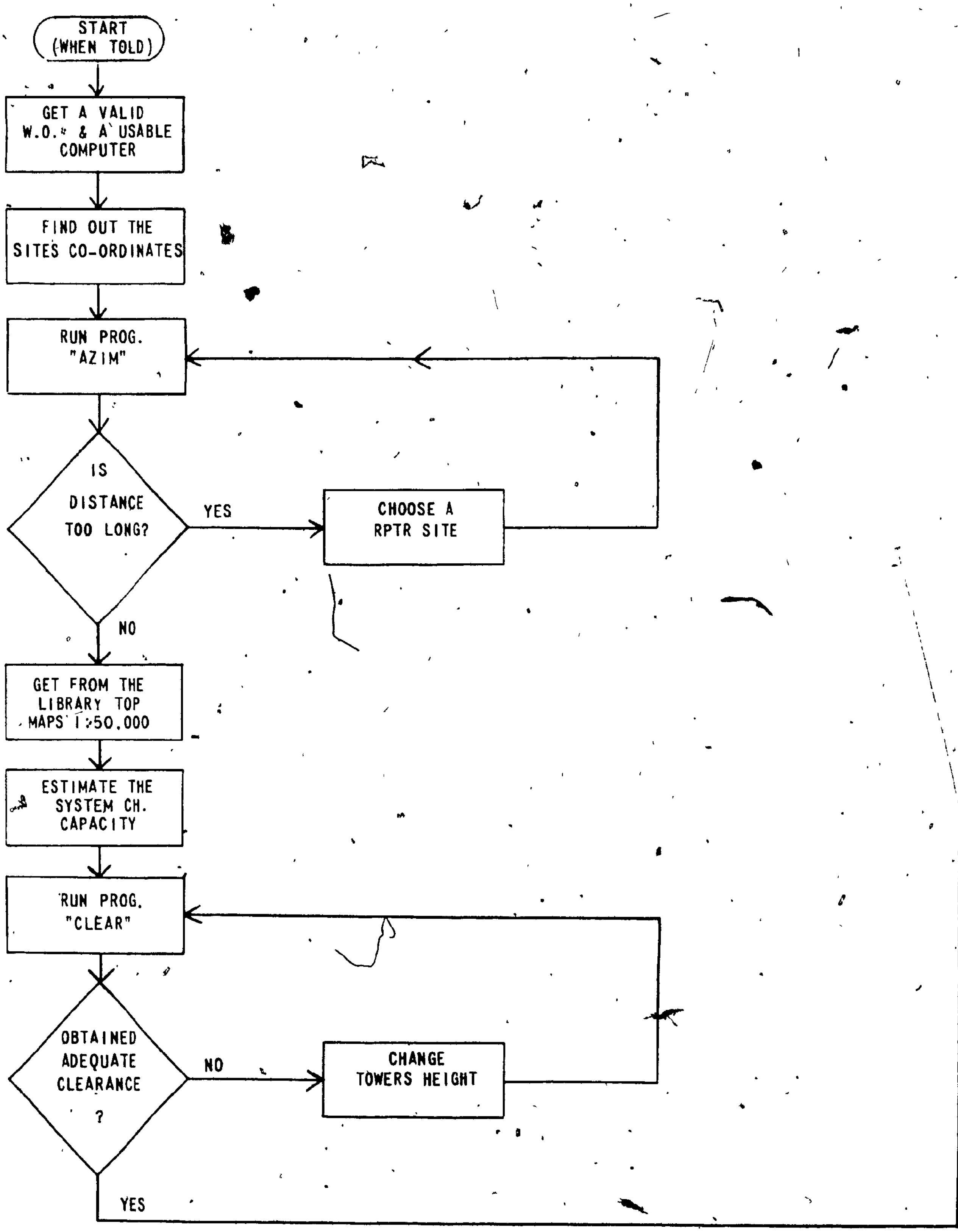

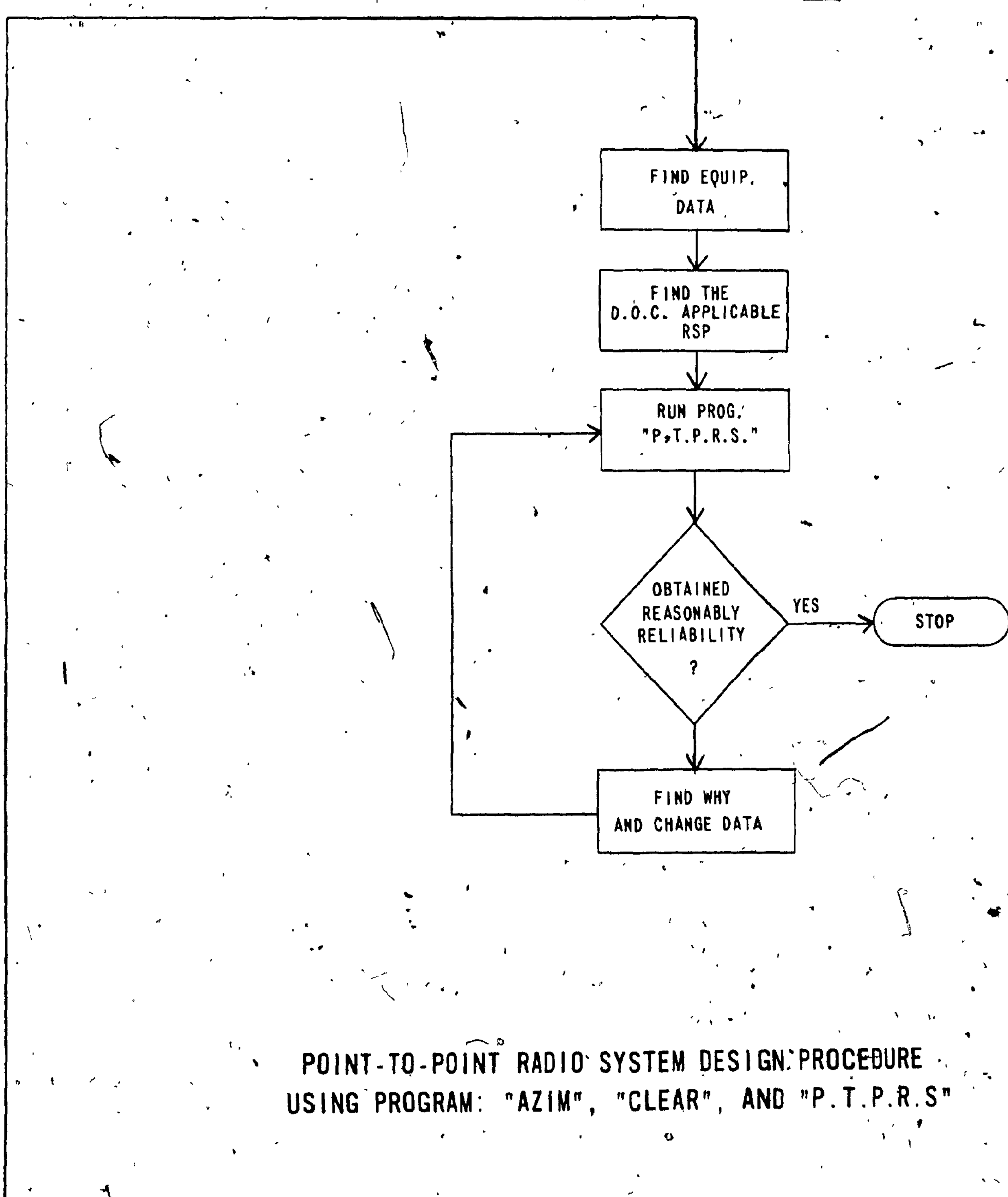

POINT-TO-POINT RADIO SYSTEM DESIGN PROCEDURE
USING PROGRAM: "AZIM", "CLEAR", AND "P.T.P.R.S"

FIG. 4.1

CHAPTER 5

CONCLUSIONS

The design of Point-to-point Radio system must include, beside the engineering study, a cost study to justify its use as the most convenient alternative. Other alternatives as Power Line Carrier, Coaxial Cables, Telephone Cables, Fibre Optics, etc. are considered competitive but normally do have certain limitations.

Microwave bands have now become the most usable bands for Point-to-point radio systems. This is due to the congestion in other bands and restricted spectrum management.

Engineering considerations for the design of radio system, as covered in this report, depends mostly on the geographical criteria of the radio path.

High Reliability Performace of Point-to-point radio systems, with diversity options, makes their choice as one of the best communication media.

A 30 to 40 dB fade margin objective figure should be considered for high reliability systems.

A 30 dB signal to noise flat (unweighted) in the top voice channel is considered the level at which receivers are squelched; (Threshold level).

Sometimes it is more practical and less expensive to use larger antenna than power amplifiers to increase the effective radiated power.

Using higher towers could, in special cases, replace the need of repeaters.

The increase of antenna height above ground is not always the right solution for improving the performance. It could be more harmful if clearances reach values equal to even fresnel number at the possible reflecting points. Special considerations should be taken if the radio beam is crossing large water surfaces [1].

Modern techniques in manufacturing microwave equipment (i.e. circulators, antennae, wave guides, parametric amplifiers, crystals, etc.) have made these bands usable for satellite communications. The future is quite promising for more development. The developed programs enclosed in this report does not replace the designer in making decisions, they only provide him with a complete analysis of the system performance according to the collected information. The designer has to select the sites, equipment and possible frequency bands.

One of the disadvantages of studying the clearance by using program CLEAR, is that the input data for the terrains are collected for 0.5 miles intervals. This could overlook a peak of a mountain that exists in between. Reducing the interval is not considered practical where the paths examined could be as much as 40 miles long. However, this program provides the designer with highly valuable information about the clearances everywhere at different earth factor and at different frequency bands. Program P.T.P.R.S considers all possible combinations of antenna gains and the corresponding achievement in the system performance.

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APPENDIX A

CONTENTS FOR APPENDIX A

FIGURES AND SAMPLES

A1.0 INTRODUCTION

Program AZIM was developed to compute the DISTANCE and inverse positon AZIMUTH between any two sites in the Northern Hemisphere. It is also usable for sites in the Southern Hamisphere, with slight changes.

Flow Chart for the program and a complete sample is shown at the end of the Appendix.

A2.0 COMPUTER LANGUAGE

The language used is Fortran IV punched on cards using BCD Format (026). It should be noted that there are references to trigonometric and logarithmic functions in this program. Some computers have a special arrangement for using these functions, i.e. they store them in LIBRARY. When used, a reference is then to be made in the compilation cards.

A3.0 INPUT AND OUTPUT DATA

The required INPUT data for this program are the sites LATITUDE & LONGITUDE. As described below each data card will represent a site. The program computes and prints out the following:-

1. W and C angles used in computations.
2. Azimuth at Station (1).
3. Azimuth at Station (2).
4. Distance between Station (1) and Station (2) in MILES, and in K.M.

A3.1 FORMAT FOR INPUT DATA CARDS

The input data cards (the cards preceding the last 6/7/8/9 blue card) starts after the 7/8/9 card terminating the main program.

They sequently hold the co-ordinates of each individual site, LATITUDE in DEGREES - MINUTES - SECONDS and LONGITUDE in DEGREES - MINUTES - SECONDS.

The format is:

(3X, F5.1, 2 (3X, F4.1), 15X, F5.1, 2 (3X, F4.1)).

When more than one link is required to be examined, more pairs of data cards could be added. The outputs will correspondingly be printed out in the same order.

The last input-data card MUST contain in columns 70, 71 and 72 Figure "9", this in turn will indicate that no more data should be read and the computer will accordingly STOP.

NOTES:

1. In case of using sites on the Southern Hemisphere use the following formula for AZIMUTH calculations:

   Case Station (2) north of Station (1)

   Az. at Station (1) = 90° - W + C

   Az. at Station (2) = 270° - W - C

   Case Station (2) south of Station (1)

   Az. at Station (1) = 90° + W + C

   Az. at Station (2) = 270° + W - C.

2. Compilation cards are obtained according to the used computer.

3. The first, third, fifth, etc. (ODD) cards should always represent sites that are more the WEST than their corresponding site, the latter are the second, fourth, sixth, etc. (EVEN) cards.

A3.2 EXAMPLE:

The distance apart and the inverse position azimuth between stations (A) and (B), and stations (B) and (C) are to be determined.

Station (A)	Name:	Charlottetown, P.E.I.			
Latitude		46°	14'	18"	N
Longitude		63°	07'	07"	W
Station (B)	Name:	Green Road, P.E.I.			
Latitude		46°	12'	06"	N
Longitude		63°	22'	26"	W
Station (C)	Name:	Borden, P.E.I.			
Latitude		46°	15'	00"	N
Longitude		63°	41'	30"	W

INPUT DATA CARDS

First pair for the (A) to (B) Link

- First card will contain Station (B) co-ordinates. *
- Second card will contain Station (A) co-ordinates.

Second pair for the (B) to (C) Link

- First card (third in position in the data cards) will contain the co-ordinates for Station (C). *
- Second card (fourth in position in the data cards) will contain the co-ordinates for Station (B). Also, this card is the last one.

  Hence, Figure "9" appears in columns 70, 71 and 72.

  See Figures 1, 2 and 3 for details of data cards.
- 6/7/8/9 and 7/8/9 cards are standard cards. Each has the above figures punched on the first column.

Output

See complete program print-out.

* First card of any pair should contain the site co-ordinates that are more to the WEST, (Longitude value is larger).

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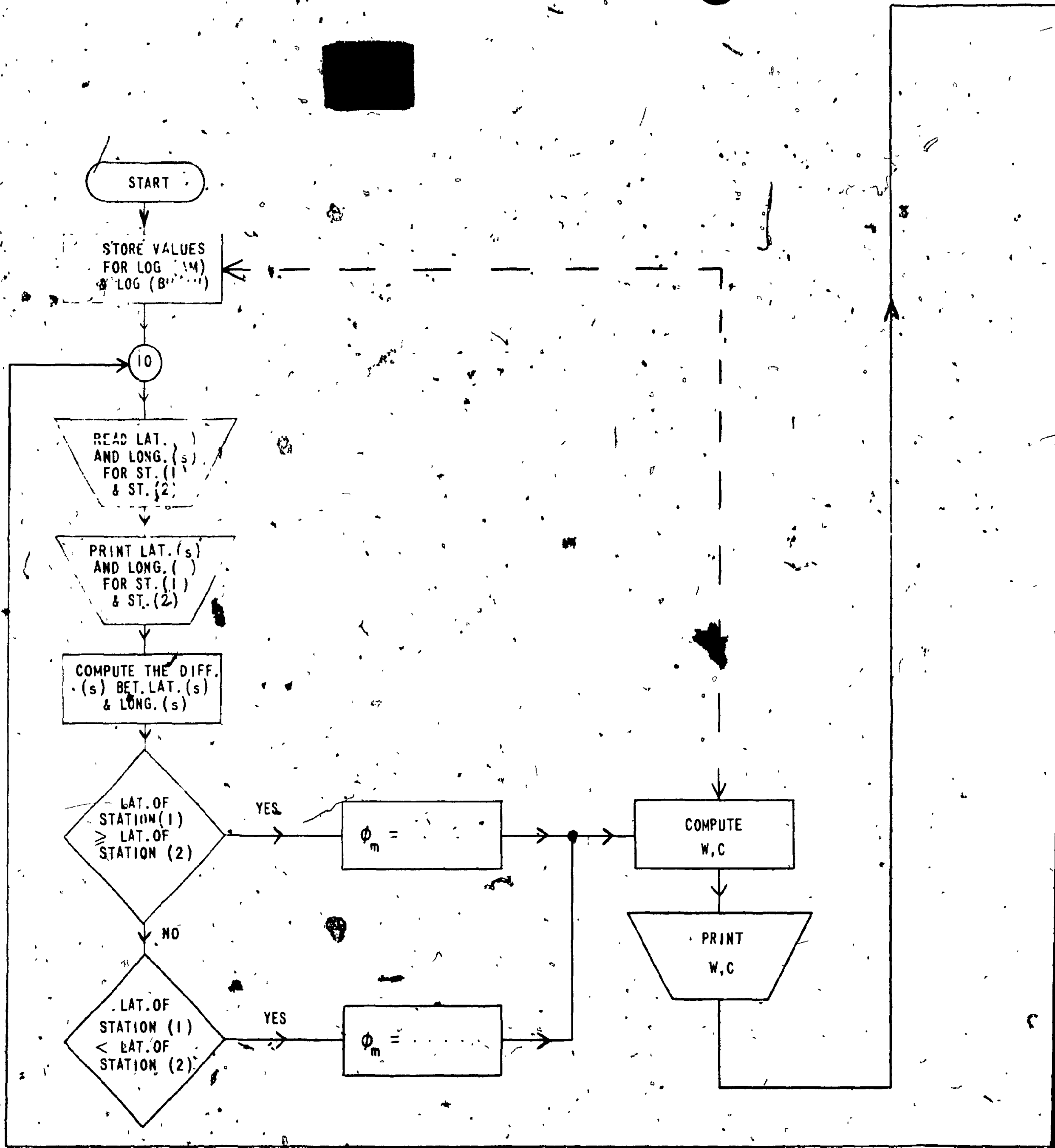
[redacted]



FLOW CHART FOR PROGRAM "A

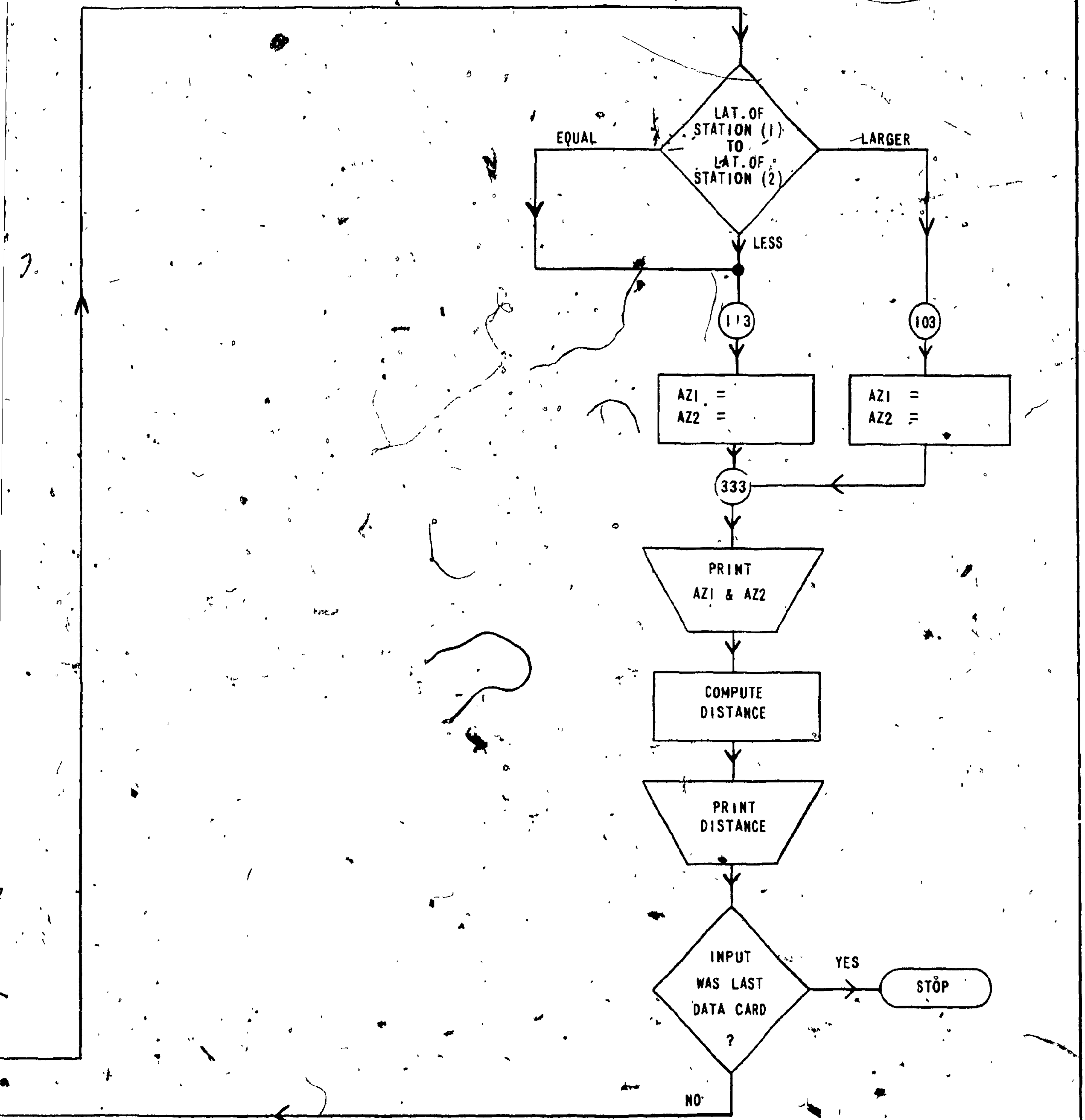


CHART FOR PROGRAM "AZIM"

```
      PROGRAM AZIM (INPUT,OUTPUT)
C        THIS PROGRAM IS TO COMPUTE THE INVERSE POSITION AZIMUTH AND
C        PATH DISTANCE BETWEEN ANY TWO SITES IN THE NORTHERN HEMISPHERE.
C        STATION 1 IS THE STATION TO THE WEST.
      DIMENSION AM(73),AB(73)
      PI=3.1415926536
      AM(1)=-1.490273
      AM(2)=-1.490274
      AM(3)=-1.490275
      AM(4)=-1.490277
      AM(5)=-1.490281
      AM(6)=-1.490285
      AM(7)=-1.490289
      AM(8)=-1.490295
      AM(9)=-1.490302
      AM(10)=-1.490309
      AM(11)=-1.490318
      AM(12)=-1.490327
      AM(13)=-1.490337
      AM(14)=-1.490348
      AM(15)=-1.490359
      AM(16)=-1.490372
      AM(17)=-1.490385
      AM(18)=-1.490399
      AM(19)=-1.490414
      AM(20)=-1.490429
      AM(21)=-1.490445
      AM(22)=-1.490462
      AM(23)=-1.490480
      AM(24)=-1.490498
      AM(25)=-1.490517
      AM(26)=-1.490536
      AM(27)=-1.490556
      AM(28)=-1.490577
      AM(29)=-1.490598
      AM(30)=-1.490619
      AM(31)=-1.490641
      AM(32)=-1.490664
      AM(33)=-1.490687
      AM(34)=-1.490710
      AM(35)=-1.490733
      AM(36)=-1.490757
      AM(37)=-1.490782
      AM(38)=-1.490806
      AM(39)=-1.490831
      AM(40)=-1.490856
      AM(41)=-1.490882
      AM(42)=-1.490907
      AM(43)=-1.490934
      AM(44)=-1.490958
      AM(45)=-1.490984
      AM(46)=-1.491010
      AM(47)=-1.491035
```

```
      AM(48)=-1.491061
      AM(49)=-1.491087
      AM(50)=-1.491112
      AM(51)=-1.491138
      AM(52)=-1.491163
      AM(53)=-1.491188
      AM(54)=-1.491213
      AM(55)=-1.491238
      AM(56)=-1.491262
      AM(57)=-1.491286
      AM(58)=-1.491310
      AM(59)=-1.491333
      AM(60)=-1.491356
      AM(61)=-1.491379
      AM(62)=-1.491401
      AM(63)=-1.491422
      AM(64)=-1.491443
      AM(65)=-1.491464
      AM(66)=-1.491484
      AM(67)=-1.491504
      AM(68)=-1.491522
      AM(69)=-1.491541
      AM(70)=-1.491558
      AM(71)=-1.491575
      AM(72)=-1.491591
      AM(73)=-1.491607
      AB(1)=0.002949
      AB(2)=0.002949
      AB(3)=0.002946
      AB(4)=0.002941
      AB(5)=0.002935
      AB(6)=0.002927
      AB(7)=0.002917
      AB(8)=0.002906
      AB(9)=0.002893
      AB(10)=0.002876
      AB(11)=0.002861
      AB(12)=0.002843
      AB(13)=0.002823
      AB(14)=0.002801
      AB(15)=0.002776
      AB(16)=0.002753
      AB(17)=0.002726
      AB(18)=0.002698
      AB(19)=0.002669
      AB(20)=0.002638
      AB(21)=0.002606
      AB(22)=0.002572
      AB(23)=0.002537
      AB(24)=0.002501
      AB(25)=0.002463
      AB(26)=0.002424
      AB(27)=0.002384
```

```
      AB(28)=0.002343
      AB(29)=0.002301
      AB(30)=0.002258
      AB(31)=0.002214
      AB(32)=0.002169
      AB(33)=0.002123
      AB(34)=0.002077
      AB(35)=0.002029
      AB(36)=0.001981
      AB(37)=0.001933
      AB(38)=0.001884
      AB(39)=0.001834
      AB(40)=0.001784
      AB(41)=0.001733
      AB(42)=0.001683
      AB(43)=0.001631
      AB(44)=0.001580
      AB(45)=0.001529
      AB(46)=0.001477
      AB(47)=0.001426
      AB(48)=0.001374
      AB(49)=0.001323
      AB(50)=0.001272
      AB(51)=0.001221
      AB(52)=0.001170
      AB(53)=0.001120
      AB(54)=0.001071
      AB(55)=0.001021
      AB(56)=0.000973
      AB(57)=0.000925
      AB(58)=0.000877
      AB(59)=0.000830
      AB(60)=0.000784
      AB(61)=0.000739
      AB(62)=0.000695
      AB(63)=0.000652
      AB(64)=0.000610
      AB(65)=0.000568
      AB(66)=0.000528
      AB(67)=0.000489
      AB(68)=0.000452
      AB(69)=0.000415
      AB(70)=0.000380
      AB(71)=0.000346
      AB(72)=0.000313
      AB(73)=0.000282
    6 FORMAT (3X,F5.1,2(3X,F4.1),15X,F5.1,2(3X,F4.1))
    8 FORMAT (3X,F5.1,2(3X,F4.1),15X,F5.1,2(3X,F4.1),T70,I3)
    9 FORMAT (/,T6,*STATION 1  *,2X,F5.1,2(3X,F4.1),7X,F5.1,2(3X,F4.1))
   11 FORMAT (/,T6,*STATION 2  *,2X,F5.1,2(3X,F4.1),7X,F5.1,2(3X,F4.1))
   16 FORMAT (1H1,T20,*L A T I T U D E S*,T46,*L O N G I T U D E S*,/,
     1T20,*-------------------*,T46,*--------------------*,/,
     2T20,*DEG.   MIN.   SEC.*,T46,*DEG.   MIN.   SEC.*,/
```

```
     3T20,*----   ----   -----*,T46,*-----   ----   -----*,)
  66 FORMAT (///,T7,*W IN DEG.=*,F9.4,T37,*C IN DEG.=*,F9.4)
  67 FORMAT (/,T7,*DISTANCE IN MILES=*,F9.4,//,
    1 T7,*DISTANCE IN K.M  =*,F9.4)
  87 FORMAT (//,T7,*AZIMUTH AT STATION 1 =*,F9.4,* DEG. - E OF TRUE N
    1*,//,T7,*AZIMUTH AT STATION 2 =*,F9.4,* DEG. - E OF TRUE N =*,/)
  10 READ 6,DL1,TL1,SL1,DG1,TG1,SG1
     READ 8,DL2,TL2,SL2,DG2,TG2,SG2,N
     PRINT 16
     PRINT 9,DL1,TL1,SL1,DG1,TG1,SG1
     PRINT 11,DL2,TL2,SL2,DG2,TG2,SG2
     AT1=DL1*3600.+TL1*60.+SL1
     AT2=DL2*3600.+TL2*60.+SL2
     ON1=DG1*3600.+TG1*60.+SG1
     ON2=DG2*3600.+TG2*60.+SG2
     DELL=ABS(AT1-AT2)
     DELG=ABS(ON1-ON2)
     IF (AT1.LE.AT2) PHM=((AT1+DELL/2.)/3600.)*(PI/180.)
     IF (AT1.GT.AT2) PHM=((AT2+DELL/2.)/3600.)*(PI/180.)
     I=PHM*(180./PI)+1.5
     S1=AB(I)+ALOG10(COS(PHM))+ALOG10(DELG)-ALOG10(DELL)
     WR=ATAN(1./10.**S1)
     WD=WR*(180./PI)
     C=DELG/2.*SIN(PHM)
     CD=C/3600.
     PRINT 66,WD,CD
     IF (AT1-AT2) 113,113,103
 103 AZ1=90.+WD-CD
     AZ2=270.+WD+CD
     GO TO 333
 113 AZ1=90.-WD-CD
     AZ2=270.-WD+CD
 333 CONTINUE
     PRINT 87,AZ1,AZ2
     DIS=ALOG10(COS(PHM))+ALOG10(DELG)-AM(I)-ALOG10(COS(WR))-4.+0.79335
     D=10.**(DIS)
     DK=D*1.6093
     PRINT 67,D,DK
     IF(N.EQ.999) STOP
     GO TO 10
     END
```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
4112 AZIM

```
VARIABLES      SN  TYPE           RELOCATION
  5555  AB         REAL       ARRAY                    5444  AM       REAL       ARRAY
  5422  AT1        REAL                                5423  AT2      REAL
  5437  AZ1        REAL                                5440  AZ2      REAL
  5435  C          REAL                                5436  CD       REAL
  5442  D          REAL                                5427  DELG     REAL
  5426  DELL       REAL                                5410  DG1      REAL
  5416  DG2        REAL                                5441  DIS      REAL
  5403  DK         REAL                                5405  DL1      REAL
  5413  DL2        REAL                                5431  I        INTEGER
  5421  N          INTEGER                             5424  ON1      REAL
  5425  ON2        REAL                                5430  PHM      REAL
  5404  PI         REAL                                5412  SG1      REAL
  5420  SG2        REAL                                5407  SL1      REAL
  5415  SL2        REAL                                5432  S1       REAL
  5411  TG1        REAL                                5417  TG2      REAL
  5406  TL1        REAL                                5414  TL2      REAL
  5434  WO         REAL                                5433  WR       REAL

FILE NAMES         MODE
     0  INPUT      FMT           2043  OUTPUT    FMT

EXTERNALS          TYPE     ARGS
        ALOG10     REAL       1 LIBRARY                    ATAN     REAL        1 LIBRARY
        COS        REAL       1 LIBRARY                    SIN      REAL        1 LIBRARY

INLINE FUNCTIONS   TYPE     ARGS
        ABS        REAL       1   INTRIN

STATEMENT LABELS
  4624  6         FMT                      4631  8        FMT                      4637  9       FMT
  4446  10                                 4646  11       FMT                      4655  16      FMT
  4707  66        FMT                      4712  67       FMT                      4722  87      FMT
     0  103            INACTIVE            4564  113                               4571  333

STATISTICS
  PROGRAM LENGTH               1560B     880
  BUFFER LENGTH                4106B    2118
```

	LATITUDES			LONGITUDES		
	DEG.	MIN.	SEC.	DEG.	MIN.	SEC.
STATION 1	46.0	12.0	6.0	63.0	22.0	26.0
STATION 2	46.0	14.0	18.0	63.0	7.0	7.0

W IN DEG.= 11.6905　　　C IN DEG.= .0922

AZIMUTH AT STATION 1 = 78.2174 DEG. - E OF TRUE N -

AZIMUTH AT STATION 2 = 258.4017 DEG. - E OF TRUE N -

DISTANCE IN MILES= 12.4980

DISTANCE IN K.M = 20.1131

	LATITUDES			LONGITUDES		
	DEG.	MIN.	SEC.	DEG.	MIN.	SEC.
STATION 1	46.0	15.0	0.0	63.0	41.0	30.0
STATION 2	46.0	12.0	6.0	63.0	22.0	26.0

W IN DEG.= 12.3600 C IN DEG.= .1147

AZIMUTH AT STATION 1 = 102.2452 DEG. - E OF TRUE N -

AZIMUTH AT STATION 2 = 282.4747 DEG. - E OF TRUE N -

DISTANCE IN MILES= 15.5951

DISTANCE IN K.M = 25.0971

```
          AEBIAVU.   76/12/02.  NOS 1.1 CONCORDIA UNIVERSITY.

13.12.21.NADER,CM60000,T20, EXPR
13.12.21.ACCOUNT,D740004,.
13.12.21.FTN.
13.12.40.     4.844 CP SECONDS COMPILATION TIME
13.12.40.ATTACH,IMSLIB/UN=LIBRARY.
13.12.42.LDSET(LIB=IMSLIB)
13.12.42.LGO.
13.12.46.       STOP
13.12.46.       .067 CP SECONDS EXECUTION TIME
13.12.46.UEPF,       0.009KUNS.
13.12.46.UEMS,       0.543KUNS.
13.12.46.UECP,       5.743SECS.
```

FIG. 1 - INPUT DATA CARD FORMAT

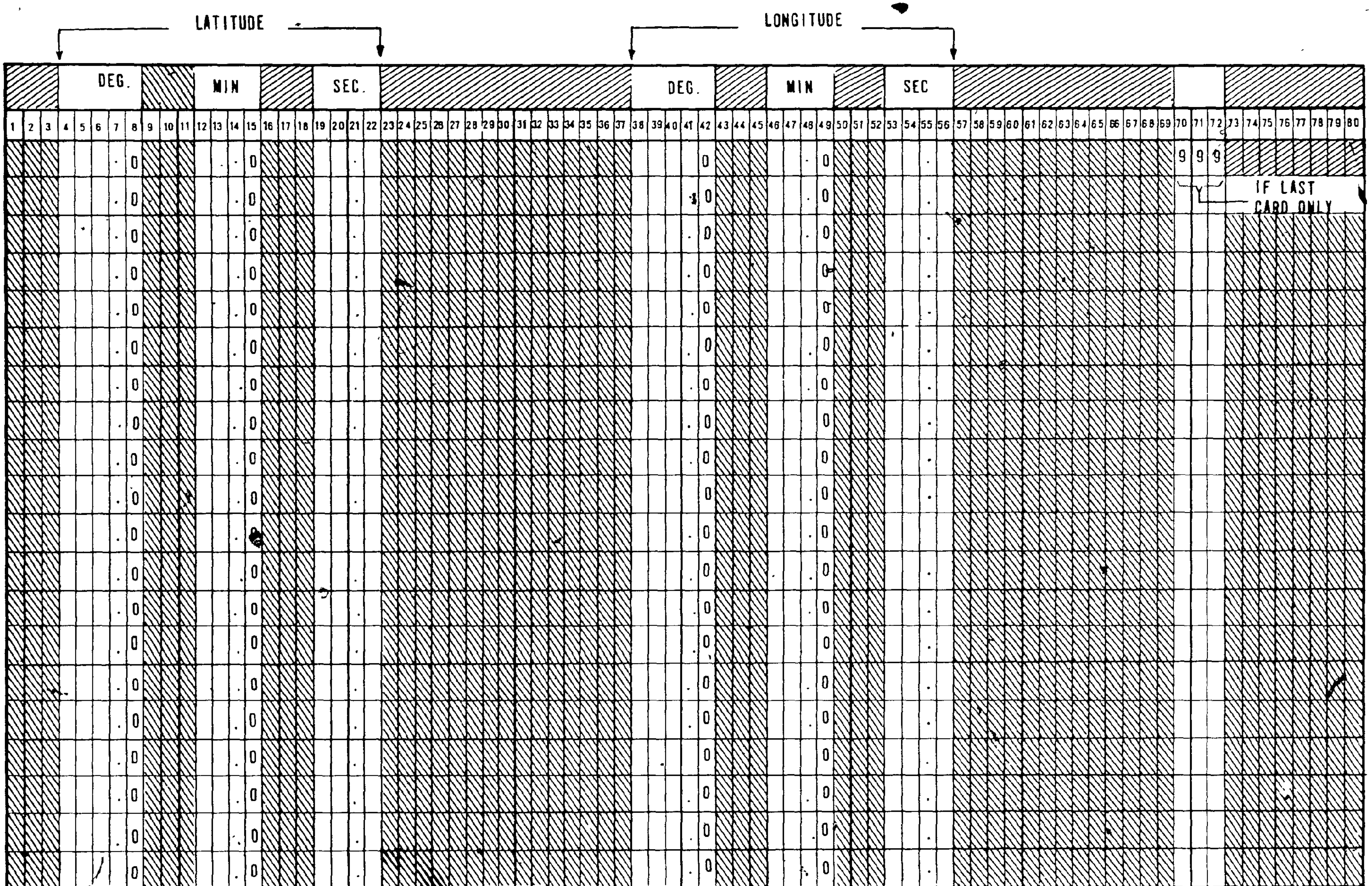


FIG. 2

INPUT DATA CARD FORMAT

FOR PROGRAM 'AZIM'

	LATITUDE			LONGITUDE			
Columns 1–3	DEG. (4–8)	MIN. (12–15)	SEC. (19–22)	DEG (38–42)	MIN. (46–49)	SEC. (53–56)	STOP CARD (70–72)
	46.0	12.0	6.0	63.0	22.0	26.0	
	46.0	14.0	8.0	63.0	7.0	7.0	
	46.0	15.0	0.0	63.0	41.0	30.0	
	46.0	12.0	6.0	63.0	22.0	26.0	999
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	
	.0	.0	.	.0	.0	.	

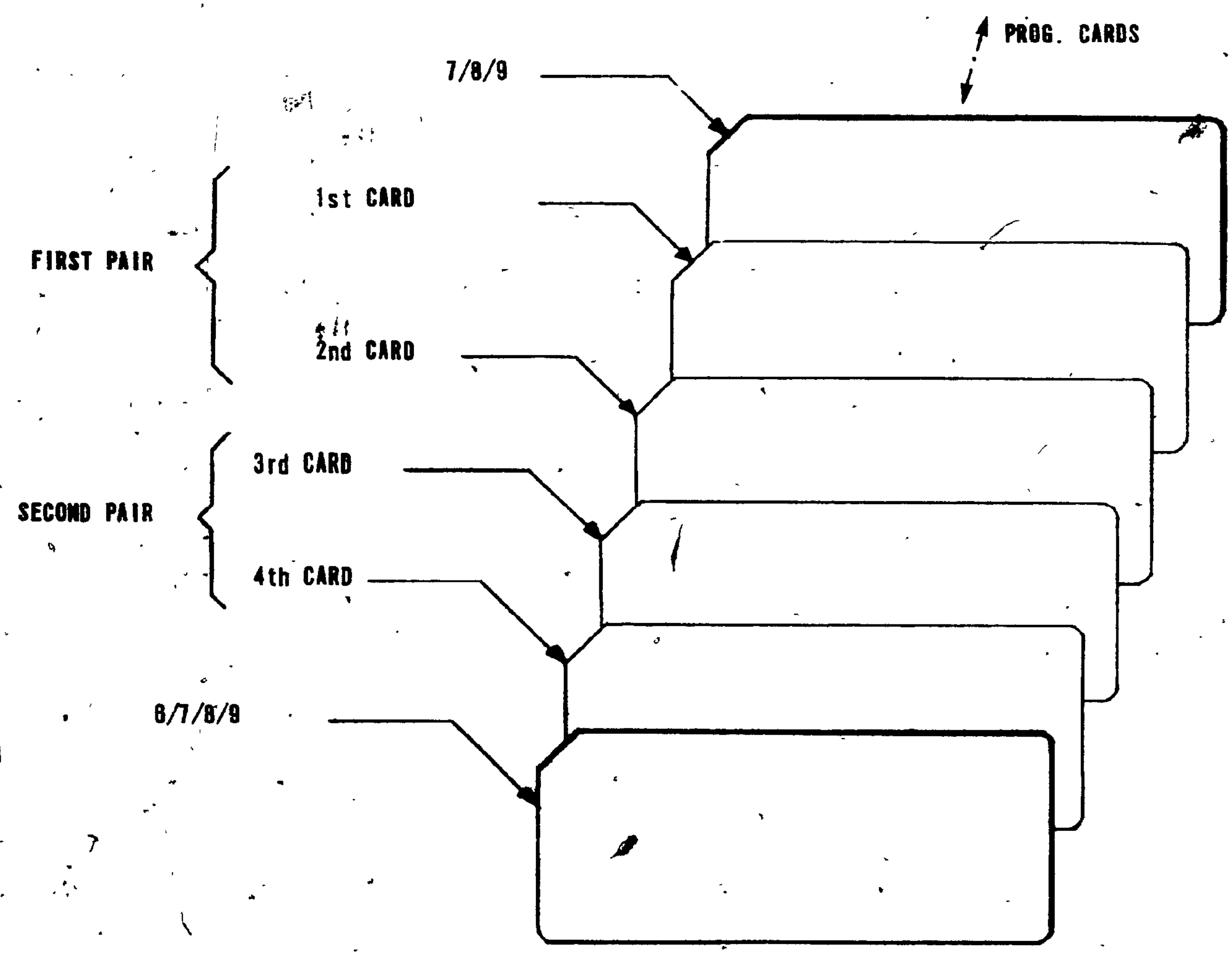


FIG. 3 - DATA (INPUT) CARDS ARRANGEMENTS

APPENDIX B

CONTENTS FOR APPENDIX B

FIGURES AND SAMPLES

B1.0 INTRODUCTION

Program "CLEAR" was developed to compute the clearance of the radio beam, relative to the first fresnel zone radius, everywhere, for different K (earth curvature factor) values, and at different carrier frequency for the same point-to-point path.

This program should give the system designer a guide to answer the following:

a) Which frequency band should be used to provide adequate path clearance with a reasonable tower height?

b) What is the exact tower height required to fulfill the required clearance?

c) Is a repeater site required?

Flow chart for this program and a complete sample of the program is shown at the end of this Appendix.

B2.0 COMPUTER LANGUAGE

The language used is Fortran IV punched on cards using BCD Format (026). It should be noted that there are references to square root function in this program. Some computers store this function, i.e. in the LIBRARY. When used as a reference, it should be made in the compilation cards to provide an access to the LIBRARY.

B3.0 INPUT DATA CARDS

The required input data for this program are as follows:

a) First input data card:

- Format (4X, F 9.4) contains the distance in miles.

b) Second input data card:

- Format (1X, 2 (3X, F 9.4) contains:

1- Ground elevation in ft. above sea level at station (1)

2- Ground elevation in ft. above sea level at station (2).

c) Third input data card:

- Format (1X, 2(3X, F 9.41) contains:

1- Tower height in ft. above ground level at station (1).

2- Tower height in ft. above ground level at station (2).

d) Fourth to the (N+3) input data cards:

- Format (4X, F 9.4) contains:

Ground elevation in ft. above sea level, (at 0.5 mile interval)

where, N = 2 x D + 1 and,

D = Distance in miles.

e) From the (N+3) card to the last data card:

- Format (4X,F9.4,T70,I3) contains on each card a carrier frequency in GHz.. The last input data card MUST contain in Columns 70, 71, and 72 Figure "9" to stop the computer.

(See Figure(s) 1 - 3 for details).

B3.1 OUTPUT

The program prints out the following:

a) For a given frequency and for

K = 0.6666, 1.0000, 1.3333, and INFINITY

1- The fresnel zone radius in (ft.) at 0.5 mile intervals.

2- The earth curvature height in (ft) at 0.5 mile intervals

3- The clearance of the radio beam in (ft) at 0.5 mile intervals.

4- The ratio of the clearance (3) abvoe to the first fresnel zone radius (1) above.

b) The program then repeats (a) above for a new frequency.

B3.2 EXAMPLE

Study the path connecting station (1) to station (2), given the following:

a) 1- Distance apart 16.9 miles

2- Ground elevation at station (1) = 10 ft above sea level
Ground elevation at station (2) = 15 ft above sea level

3- Tower height at station (1) = 100 ft above ground
Tower height at station (2) = 100 ft above ground

b) The ground elevation taken off topographical maps at 0.5 mile intervals are as follows:

at distance 0.0 mile elevation = 10 ft above sea level
at distance 0.5 mile elevation = 5 ft above sea level
at distance 1.0 mile elevation = 0 ft above sea level
at distance 1.5 mile elevation = 0 ft above sea level
at distance 2.0 mile elevation = 0 ft above sea level
at distance 2.5 mile elevation - 0 ft above sea level
at distance 3.0 mile elevation = 0 ft above sea level
at distance 3.5 mile elevation = 0 ft above sea level
at distance 4.0 mile elevation - 0 ft above sea level
at distance 4.5 mile elevation = 0 ft above sea level

at distance 5.0 mile elevation = 0 ft above sea level

at distance 5.5 mile elevation = 0 ft above sea level

at distance 6.0 mile elevation = 0 ft above sea level

at distance 6.5 mile elevation = 0 ft above sea level

at distance 7.0 mile elevation = 0 ft above sea level

at distance 7.5 mile elevation = 0 ft above sea level

at distance 8.0 mile elevation = 0 ft abvoe sea level

at distance 8.5 mile elevation = 0 ft above sea level

at distance 9.0 mile elevation = 0 ft above sea level

at distance 9.5 mile elevation = 0 ft above sea level

at distance 10.0 mile elevation = 0 ft above sea level

at distance 10.5 mile elevation = 0 ft above sea level

at distance 11.0 mile elevation = 0 ft above sea level

at distance 11.5 mile elevation = 0 ft above sea level

at distance 12.0 mile elevation = 0 ft above sea level

at distance 12.5 mile elevation = 0 ft above sea level

at distance 13.0 mile elevation = 0 ft above sea level

at distance 13.5 mile elevation = 0 ft above sea level

at distance 14.0 mile elevation = 0 ft above sea level

at distance 14.5 mile elevation = 50 ft above sea level

at distance 15.0 mile elevation = 75 ft above sea level

at distance 15.5 mile elevation = 125 ft above sea level

at distance 16.0 mile elevation = 90 ft above sea level

at distance 16.5 mile elevation = 75 ft above sea level

c) At F = 7.125 GHz

and, F = 1.9 GHz

and, F = 0.925 GHz

(See details of input data cards in Fig. 3).

<u>Output</u>

See complete program print-out.

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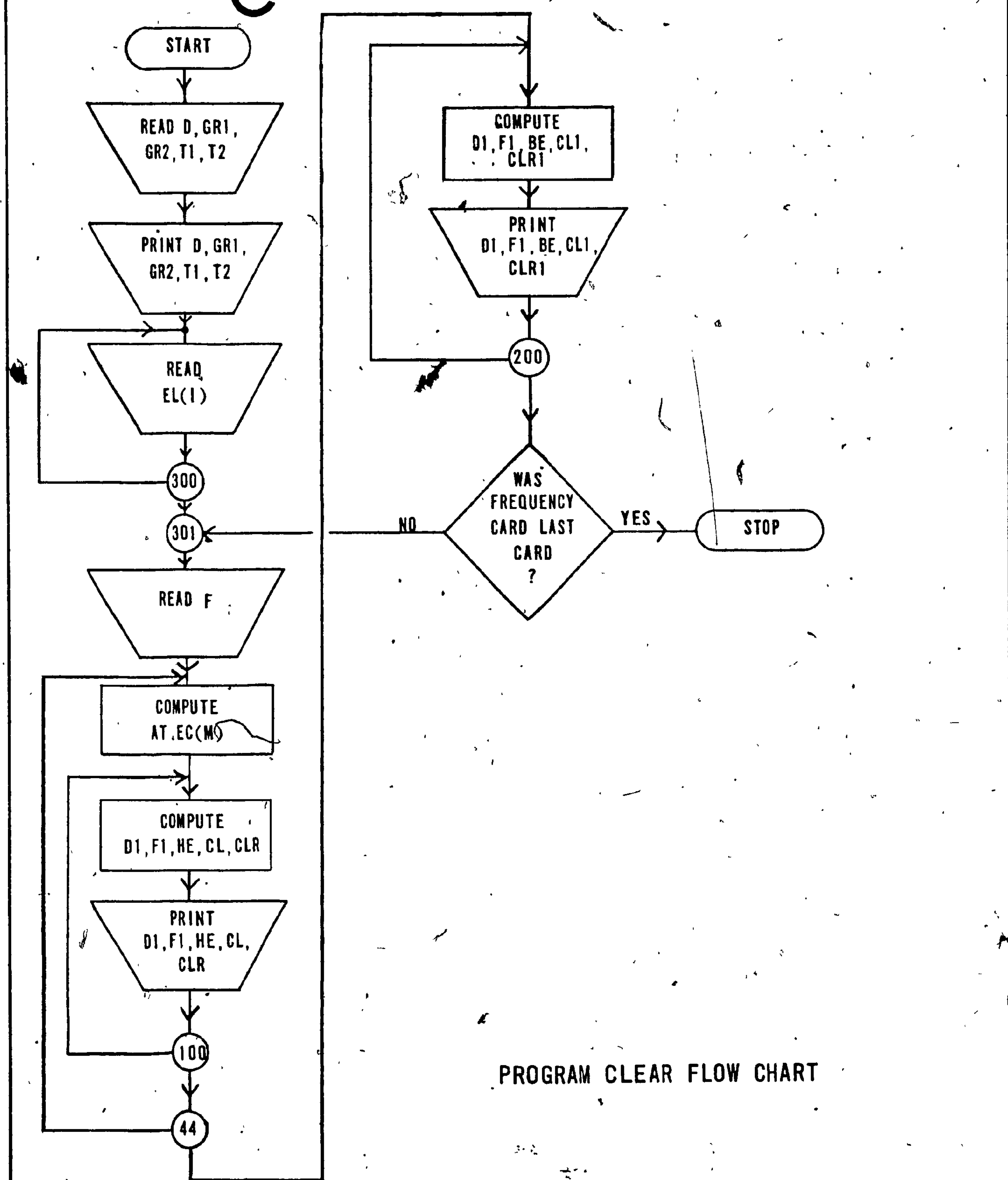


PROGRAM CLEAR FLOW CHART

```
C   THIS PROGRAM IS TO COMPUTE THE CLEARANCE OF THE RADIO BEAM,
C   RELATIVE TO THE FIRST FRESNEL ZONE RADIUS,EVERYWHERE FOR
C   DIFFERENT K VALUES,AT DIFFERENT FREQUENCIES FOR A GIVEN
C   PATH.
C   THE UNITS OF THE USED PARAMETERS ARE AS FOLLOWS=
C        D=DISTANCE IN MILES.
C        F=FREQUENCY IN GEGAHERTZ.
C        GR1=GROUND ELEVATION AT STATION 1 IN FT. ABOVE SEA LEVEL.
C        GR2=GROUND ELEVATION AT STATION 2 IN FT. ABOVE SEA LEVEL.
C        T1=TOWER HEIGHT AT STATION 1 IN FT. ABOVE GROUND LEVEL.
C        T2=TOWER HEIGHT AT STATION 2 IN FT. ABOVE GROUND LEVEL.
C        EL=ELEVATION OF GROUND IN FT. (SHOULD BE  TAKEN OFF MAPS).
      PROGRAM CLEAR (INPUT,OUTPUT)
      DIMENSION EC(3),EL(121)
      READ 2,D
      READ 1,GR1,GR2
      READ 1,T1,T2
      PRINT 12,D
      PRINT 11,GR1,GR2
      PRINT 13,T1,T2
    1 FORMAT (1X,2(3X,F9.4))
    2 FORMAT (4X,F9.4)
    4 FORMAT (1H1,T7,*GROUND ELEVATION (OFF MAPS)*,/,
     1T7,*----------------------------*,/)
    5 FORMAT (/,T14,F9.4)
    6 FORMAT (4X,F9.4,T70,I3)
   11 FORMAT (//,T7,*GR1 =*,F9.4,T37,*GR2 =*,F9.4)
   12 FORMAT (1H1,//,T7,*D =*,F9.4)
   13 FORMAT (//,T7,*T1  =*,F9.4,T37,*T2  =*,F9.4)
  101 FORMAT (/,T7,*D1 IN MILES *,T37,*F1 IN FT.*,T67,*HE IN FT.*,T97,*
     +CL IN FT.*,T127,*CLR RATIO*,/,
     1T7,*------------*,T37,*----------*,T67,*----------*,T97,* ---------*,
     2T127,*-----------*,/)
  102 FORMAT   (T7,F7.1,T37,F7.1,T67,F7.1,T97,F7.1,T127,F7.1,* F1*,)
  111 FORMAT (1H1,//, T7,*PATH STUDIED AT F =*,F9.4,T38,*GHZ*,//,T7,
     1*EARTH K FACTOR*,/,T7,*----------------*,)
  201 FORMAT (/,T7,*INFINITY*,)
      H1=GR1+T1
      H2=GR2+T2
      N=2.*D+1.
      PRINT 4
      DO 300 I=1,N
      READ 2,EL(I)
      PRINT 5,EL(I)
  300 CONTINUE
      EC(1)=0.6666
      EC(2)=1.0000
      EC(3)=1.3333
  301 READ 6,F,K
      DO 44 M=1,3
      PRINT 111,F
      PRINT 2,EC(M)
      PRINT 101
```

```
      DO 100 I=1,N
      D1=(I-1.)*0.5
      F1=72.1*SQRT((D1*(D-D1))/(F*D))
      HE=(D1*(D-D1))/(1.5*EC(M))
      H=(D1*(H2-H1)/D)+H1
      Q=HE+EL(I)
      CL=H-Q
      CLR=CL/F1
      PRINT 102,D1,F1,HE,CL,CLR
  100 CONTINUE
   44 CONTINUE
      PRINT 111,F
      PRINT 201
      PRINT 101
      DO 200 I=1,N
      D1=(I-1.)*0.5
      H=(D1*(H2-H1)/D)+H1
      F1=72.1*SQRT((D1*(D-D1))/(F*D))
      BE=0.0
      Q1=BE+EL(I)
      CL1=H-Q1
      CLR1=CL1/F1
      PRINT 102,D1,F1,BE,CL1,CLR1
  200 CONTINUE
      IF(K.EQ.999) STOP
      GO TO 301
      END
```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
4112 CLEAR

VARIABLES		SN	TYPE	RELOCATION				
4563	BE		REAL		4561	CL	REAL	
4562	CLR		REAL		4566	CLR1	REAL	
4565	CL1		REAL		4540	D	REAL	
4554	D1		REAL		4567	EC	REAL	ARRAY
4572	EL		REAL	ARRAY	4551	F	REAL	
4555	F1		REAL		4541	GR1	REAL	
4542	GR2		REAL		4557	H	REAL	
4556	HE		REAL		4545	H1	REAL	
4546	H2		REAL		4550	I	INTEGER	
4552	K		INTEGER		4553	M	INTEGER	
4547	N		INTEGER		4560	Q	REAL	
4564	Q1		REAL		4543	T1	REAL	
4544	T2		REAL					

```
          PROGRAM CLEAR       73/73    OPT=1                              FTN 4.6+420        76/12/08. 08.23.33        PAGE      3

 FILE NAMES        MODE
     0  INPUT      FMT            2043  OUTPUT     FMT

 EXTERNALS          TYPE    ARGS
        SQRT        REAL      1 LIBRARY

 STATEMENT LABELS
   4327  1         FMT                        4332  2          FMT                          4334  4          FMT
   4345  5         FMT                        4350  6          FMT                          4353  11         FMT
   4360  12        FMT                        4364  13         FMT                             0  44
      0  100                                  4371  101        FMT                          4414  102        FMT
   4423  111       FMT                           0  200                                     4436  201        FMT
      0  300                                  4160  301

 LOOPS  LABEL    INDEX      FROM-TO    LENGTH    PROPERTIES
   4141  300     * I         42 45      138B              EXT REFS
   4163  44      * M         50 64      45B               EXT REFS  NOT INNER
   4174  100     * I         54 63      31B               EXT REFS
   4236  200     * I         68 77      26B               EXT REFS

 STATISTICS
   PROGRAM LENGTH               655B      429
   BUFFER LENGTH               4106B     2118
```

D = 16.9000

GR1 = 10.0000   GR2 = 75.0000

T1 = 100.0000   T2 = 100.0000

GROUND ELEVATION (OFF MAPS)

10.0000
5.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
0.0000
50.0000

75.0000
125.0000
90.0000
75.0000

PATH STUDIED AT F = 7.1250 GHZ

EARTH K FACTOR

.6666

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	18.8	8.2	98.7	5.2 F1
1.0	26.2	15.9	97.9	3.7 F1
1.5	31.6	23.1	92.7	2.9 F1
2.0	35.9	29.8	87.9	2.5 F1
2.5	39.4	36.0	83.6	2.1 F1
3.0	42.4	41.7	79.8	1.9 F1
3.5	45.0	46.9	76.6	1.7 F1
4.0	47.2	51.6	73.8	1.6 F1
4.5	49.1	55.8	71.5	1.5 F1
5.0	50.7	59.5	69.7	1.4 F1
5.5	52.0	62.7	68.4	1.3 F1
6.0	53.1	65.4	67.7	1.3 F1
6.5	54.0	67.6	67.4	1.2 F1
7.0	54.7	69.3	67.6	1.2 F1
7.5	55.2	70.5	68.3	1.2 F1
8.0	55.4	71.2	69.6	1.3 F1
8.5	55.5	71.4	71.3	1.3 F1
9.0	55.4	71.1	73.5	1.3 F1
9.5	55.1	70.3	76.2	1.4 F1
10.0	54.6	69.0	79.5	1.5 F1
10.5	53.9	67.2	83.2	1.5 F1
11.0	52.9	64.9	87.4	1.7 F1
11.5	51.8	62.1	92.1	1.8 F1
12.0	50.4	58.8	97.3	1.9 F1
12.5	48.7	55.0	103.1	2.1 F1
13.0	46.8	50.7	109.3	2.3 F1
13.5	44.5	45.9	116.0	2.6 F1
14.0	41.9	40.6	123.2	2.9 F1
14.5	38.8	34.8	81.0	2.1 F1
15.0	35.1	28.5	64.2	1.8 F1
15.5	30.6	21.7	22.9	.7 F1
16.0	24.9	14.4	67.1	2.7 F1
16.5	16.9	6.6	91.9	5.4 F1

PATH STUDIED AT F = 7.1250 GHZ

EARTH K FACTOR

1.0000

DI IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	10.8	5.5	101.5	5.4 F1
1.0	26.2	10.6	103.2	3.9 F1
1.5	31.6	15.4	100.4	3.2 F1
2.0	35.9	19.9	97.8	2.7 F1
2.5	39.4	24.0	95.6	2.4 F1
3.0	42.4	27.8	93.7	2.2 F1
3.5	45.0	31.3	92.2	2.0 F1
4.0	47.2	34.4	91.0	1.9 F1
4.5	49.1	37.2	90.1	1.8 F1
5.0	50.7	39.7	89.6	1.8 F1
5.5	52.0	41.8	89.4	1.7 F1
6.0	53.1	43.6	89.5	1.7 F1
6.5	54.0	45.1	89.9	1.7 F1
7.0	54.7	46.2	90.7	1.7 F1
7.5	55.2	47.0	91.8	1.7 F1
8.0	55.4	47.5	93.3	1.7 F1
8.5	55.5	47.6	95.1	1.7 F1
9.0	55.4	47.4	97.2	1.8 F1
9.5	55.1	46.9	99.7	1.8 F1
10.0	54.6	46.0	102.5	1.9 F1
10.5	53.9	44.8	105.6	2.0 F1
11.0	52.9	43.3	109.0	2.1 F1
11.5	51.8	41.4	112.8	2.2 F1
12.0	50.4	39.2	117.0	2.3 F1
12.5	48.7	36.7	121.4	2.5 F1
13.0	46.8	33.8	126.2	2.7 F1
13.5	44.5	30.6	131.3	3.0 F1
14.0	41.9	27.1	136.8	3.3 F1
14.5	38.8	23.2	92.6	2.4 F1
15.0	35.1	19.0	73.7	2.1 F1
15.5	30.6	14.5	30.1	1.0 F1
16.0	24.9	9.6	71.9	2.9 F1
16.5	16.9	4.4	94.1	5.6 F1

PATH STUDIED AT F = 7.1250 GHZ

EARTH K FACTOR

1.3333

DI IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	18.8	4.1	102.8	5.5 F1
1.0	26.2	8.0	105.9	4.0 F1
1.5	31.6	11.6	104.2	3.3 F1
2.0	35.9	14.9	102.8	2.9 F1
2.5	39.4	18.0	101.6	2.6 F1
3.0	42.4	20.9	100.7	2.4 F1
3.5	45.0	23.5	100.0	2.2 F1
4.0	47.2	25.8	99.6	2.1 F1
4.5	49.1	27.9	99.4	2.0 F1
5.0	50.7	29.8	99.5	2.0 F1
5.5	52.0	31.4	99.8	1.9 F1
6.0	53.1	32.7	100.4	1.9 F1
6.5	54.0	33.8	101.2	1.9 F1
7.0	54.7	34.7	102.3	1.9 F1
7.5	55.2	35.3	103.6	1.9 F1
8.0	55.4	35.6	105.2	1.9 F1
8.5	55.5	35.7	107.0	1.9 F1
9.0	55.4	35.6	109.1	2.0 F1
9.5	55.1	35.2	111.4	2.0 F1
10.0	54.6	34.5	114.0	2.1 F1
10.5	53.9	33.6	116.8	2.2 F1
11.0	52.9	32.5	119.9	2.3 F1
11.5	51.8	31.1	123.2	2.4 F1
12.0	50.4	29.4	126.8	2.5 F1
12.5	48.7	27.5	130.6	2.7 F1
13.0	46.8	25.4	134.6	2.9 F1
13.5	44.5	23.0	139.0	3.1 F1
14.0	41.9	20.3	143.5	3.4 F1
14.5	38.8	17.4	98.4	2.5 F1
15.0	35.1	14.3	78.4	2.2 F1
15.5	30.6	10.9	33.8	1.1 F1
16.0	24.9	7.2	74.3	3.0 F1
16.5	16.9	3.3	95.2	5.6 F1

PATH STUDIED AT F = 7.1250 GHZ

EARTH K FACTOR

INFINITY

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	18.8	0.0	106.9	5.7 F1
1.0	26.2	0.0	113.8	4.3 F1
1.5	31.6	0.0	115.8	3.7 F1
2.0	35.9	0.0	117.7	3.3 F1
2.5	39.4	0.0	119.6	3.0 F1
3.0	42.4	0.0	121.5	2.9 F1
3.5	45.0	0.0	123.5	2.7 F1
4.0	47.2	0.0	125.4	2.7 F1
4.5	49.1	0.0	127.3	2.6 F1
5.0	50.7	0.0	129.2	2.5 F1
5.5	52.0	0.0	131.2	2.5 F1
6.0	53.1	0.0	133.1	2.5 F1
6.5	54.0	0.0	135.0	2.5 F1
7.0	54.7	0.0	136.9	2.5 F1
7.5	55.2	0.0	138.8	2.5 F1
8.0	55.4	0.0	140.8	2.5 F1
8.5	55.5	0.0	142.7	2.6 F1
9.0	55.4	0.0	144.6	2.6 F1
9.5	55.1	0.0	146.5	2.7 F1
10.0	54.6	0.0	148.5	2.7 F1
10.5	53.9	0.0	150.4	2.8 F1
11.0	52.9	0.0	152.3	2.9 F1
11.5	51.8	0.0	154.2	3.0 F1
12.0	50.4	0.0	156.2	3.1 F1
12.5	48.7	0.0	158.1	3.2 F1
13.0	46.8	0.0	160.0	3.4 F1
13.5	44.5	0.0	161.9	3.6 F1
14.0	41.9	0.0	163.8	3.9 F1
14.5	38.8	0.0	115.8	3.0 F1
15.0	35.1	0.0	92.7	2.6 F1
15.5	30.6	0.0	44.6	1.5 F1
16.0	24.9	0.0	81.5	3.3 F1
16.5	16.9	0.0	98.5	5.8 F1

PATH STUDIED AT F = 1.9000 GHZ

EARTH K FACTOR

.6666

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	36.4	8.2	98.7	2.7 F1
1.0	50.7	15.9	97.9	1.9 F1
1.5	61.2	23.1	92.7	1.5 F1
2.0	69.5	29.8	87.9	1.3 F1
2.5	76.3	36.0	83.6	1.1 F1
3.0	82.2	41.7	79.8	1.0 F1
3.5	87.1	46.9	76.6	.9 F1
4.0	91.4	51.6	73.8	.8 F1
4.5	95.0	55.8	71.5	.8 F1
5.0	98.1	59.5	69.7	.7 F1
5.5	100.8	62.7	68.4	.7 F1
6.0	102.9	65.4	67.7	.7 F1
6.5	104.6	67.6	67.4	.6 F1
7.0	105.9	69.3	67.6	.6 F1
7.5	106.8	70.5	68.3	.6 F1
8.0	107.4	71.2	69.6	.6 F1
8.5	107.5	71.4	71.3	.7 F1
9.0	107.3	71.1	73.5	.7 F1
9.5	106.7	70.3	76.2	.7 F1
10.0	105.7	69.0	79.5	.8 F1
10.5	104.3	67.2	83.2	.8 F1
11.0	102.5	64.9	87.4	.9 F1
11.5	100.3	62.1	92.1	.9 F1
12.0	97.6	58.8	97.3	1.0 F1
12.5	94.4	55.0	103.1	1.1 F1
13.0	90.6	50.7	109.3	1.2 F1
13.5	86.2	45.9	116.0	1.3 F1
14.0	81.1	40.6	123.2	1.5 F1
14.5	75.1	34.8	81.6	1.1 F1
15.0	67.9	28.5	64.2	.9 F1
15.5	59.3	21.7	22.9	.4 F1
16.0	48.3	14.4	67.1	1.4 F1
16.5	32.7	6.6	91.9	2.8 F1

PATH STUDIED AT F = 1.9000 GHZ

EARTH K FACTOR

1.0000

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	36.4	5.5	101.5	2.8 F1
1.0	50.7	10.6	103.2	2.0 F1
1.5	61.2	15.4	100.4	1.6 F1
2.0	69.5	19.9	97.8	1.4 F1
2.5	76.3	24.0	95.6	1.3 F1
3.0	82.2	27.8	93.7	1.1 F1
3.5	87.1	31.3	92.2	1.1 F1
4.0	91.4	34.4	91.0	1.0 F1
4.5	95.0	37.2	90.1	.9 F1
5.0	98.1	39.7	89.6	.9 F1
5.5	100.8	41.8	89.4	.9 F1
6.0	102.9	43.6	89.5	.9 F1
6.5	104.6	45.1	89.9	.9 F1
7.0	105.9	46.2	90.7	.9 F1
7.5	106.8	47.0	91.8	.9 F1
8.0	107.4	47.5	93.3	.9 F1
8.5	107.5	47.6	95.1	.9 F1
9.0	107.3	47.4	97.2	.9 F1
9.5	106.7	46.9	99.7	.9 F1
10.0	105.7	46.0	102.5	1.0 F1
10.5	104.3	44.8	105.6	1.0 F1
11.0	102.5	43.3	109.0	1.1 F1
11.5	100.3	41.4	112.8	1.1 F1
12.0	97.6	39.2	117.0	1.2 F1
12.5	94.4	36.7	121.4	1.3 F1
13.0	90.6	33.8	126.2	1.4 F1
13.5	86.2	30.6	131.3	1.5 F1
14.0	81.1	27.1	136.8	1.7 F1
14.5	75.1	23.2	92.6	1.2 F1
15.0	67.9	19.0	73.7	1.1 F1
15.5	59.3	14.5	30.1	.5 F1
16.0	48.3	9.6	71.9	1.5 F1
16.5	32.7	4.4	94.1	2.9 F1

PATH STUDIED AT F = 1.9000 GHZ

EARTH K FACTOR

1.3333

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	36.4	4.1	102.8	2.8 F1
1.0	50.7	8.0	105.9	2.1 F1
1.5	61.2	11.6	104.2	1.7 F1
2.0	69.5	14.9	102.8	1.5 F1
2.5	76.3	18.0	101.6	1.3 F1
3.0	82.2	20.9	100.7	1.2 F1
3.5	87.1	23.5	100.0	1.1 F1
4.0	91.4	25.8	99.6	1.1 F1
4.5	95.0	27.9	99.4	1.0 F1
5.0	98.1	29.8	99.5	1.0 F1
5.5	100.8	31.4	99.8	1.0 F1
6.0	102.9	32.7	100.4	1.0 F1
6.5	104.6	33.8	101.2	1.0 F1
7.0	105.9	34.7	102.3	1.0 F1
7.5	106.8	35.3	103.6	1.0 F1
8.0	107.4	35.6	105.2	1.0 F1
8.5	107.5	35.7	107.0	1.0 F1
9.0	107.3	35.6	109.1	1.0 F1
9.5	106.7	35.2	111.4	1.0 F1
10.0	105.7	34.5	114.0	1.1 F1
10.5	104.3	33.6	116.8	1.1 F1
11.0	102.5	32.5	119.9	1.2 F1
11.5	100.3	31.1	123.2	1.2 F1
12.0	97.6	29.4	126.8	1.3 F1
12.5	94.4	27.5	130.6	1.4 F1
13.0	90.6	25.4	134.6	1.5 F1
13.5	86.2	23.0	139.0	1.6 F1
14.0	81.1	20.3	143.5	1.8 F1
14.5	75.1	17.4	98.4	1.3 F1
15.0	67.9	14.3	78.4	1.2 F1
15.5	59.3	10.9	33.8	.6 F1
16.0	48.3	7.2	74.3	1.5 F1
16.5	32.7	3.3	95.2	2.9 F1

PATH STUDIED AT F = 1.9000 GHZ

EARTH K FACTOR

INFINITY

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	36.4	0.0	106.9	2.9 F1
1.0	50.7	0.0	113.8	2.2 F1
1.5	61.2	0.0	115.8	1.9 F1
2.0	69.5	0.0	117.7	1.7 F1
2.5	76.3	0.0	119.6	1.6 F1
3.0	82.2	0.0	121.5	1.5 F1
3.5	87.1	0.0	123.5	1.4 F1
4.0	91.4	0.0	125.4	1.4 F1
4.5	95.0	0.0	127.3	1.3 F1
5.0	98.1	0.0	129.2	1.3 F1
5.5	100.8	0.0	131.2	1.3 F1
6.0	102.9	0.0	133.1	1.3 F1
6.5	104.6	0.0	135.0	1.3 F1
7.0	105.9	0.0	136.9	1.3 F1
7.5	106.8	0.0	138.8	1.3 F1
8.0	107.4	0.0	140.8	1.3 F1
8.5	107.5	0.0	142.7	1.3 F1
9.0	107.3	0.0	144.6	1.3 F1
9.5	106.7	0.0	146.5	1.4 F1
10.0	105.7	0.0	148.5	1.4 F1
10.5	104.3	0.0	150.4	1.4 F1
11.0	102.5	0.0	152.3	1.5 F1
11.5	100.3	0.0	154.2	1.5 F1
12.0	97.6	0.0	156.2	1.6 F1
12.5	94.4	0.0	158.1	1.7 F1
13.0	90.6	0.0	160.0	1.8 F1
13.5	86.2	0.0	161.9	1.9 F1
14.0	81.1	0.0	163.8	2.0 F1
14.5	75.1	0.0	115.8	1.5 F1
15.0	67.9	0.0	92.7	1.4 F1
15.5	59.3	0.0	44.6	.8 F1
16.0	48.3	0.0	81.5	1.7 F1
16.5	32.7	0.0	98.5	3.0 F1

PATH STUDIED AT F = .9250 GHZ

EARTH K FACTOR

.6666

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	52.2	8.2	98.7	1.9 F1
1.0	72.7	15.9	97.9	1.3 F1
1.5	87.6	23.1	92.7	1.1 F1
2.0	99.5	29.8	87.9	.9 F1
2.5	109.4	36.0	83.6	.8 F1
3.0	117.8	41.7	79.8	.7 F1
3.5	124.9	46.9	76.6	.6 F1
4.0	131.0	51.6	73.8	.6 F1
4.5	136.2	55.8	71.5	.5 F1
5.0	140.7	59.5	69.7	.5 F1
5.5	144.4	62.7	68.4	.5 F1
6.0	147.5	65.4	67.7	.5 F1
6.5	149.9	67.6	67.4	.4 F1
7.0	151.8	69.3	67.6	.4 F1
7.5	153.1	70.5	68.3	.4 F1
8.0	153.9	71.2	69.6	.5 F1
8.5	154.1	71.4	71.3	.5 F1
9.0	153.8	71.1	73.5	.5 F1
9.5	152.9	70.3	76.2	.5 F1
10.0	151.5	69.0	79.5	.5 F1
10.5	149.5	67.2	83.2	.6 F1
11.0	146.9	64.9	87.4	.6 F1
11.5	143.7	62.1	92.1	.6 F1
12.0	139.8	58.8	97.3	.7 F1
12.5	135.2	55.0	10[illegible].1	.8 F1
13.0	129.8	50.7	10[illegible].3	.8 F1
13.5	123.5	45.9	116.0	.9 F1
14.0	116.2	40.6	123.2	1.1 F1
14.5	107.6	34.8	81.0	.8 F1
15.0	97.4	28.5	64.2	.7 F1
15.5	84.9	21.7	22.9	.3 F1
16.0	69.2	14.4	67.1	1.0 F1
16.5	46.8	6.6	91.9	2.0 F1

PATH STUDIED AT F = .9250 GHZ

EARTH K FACTOR

1.0000

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	52.2	5.5	101.5	1.9 F1
1.0	72.7	10.6	103.2	1.4 F1
1.5	87.6	15.4	100.4	1.1 F1
2.0	99.5	19.9	97.8	1.0 F1
2.5	109.4	24.0	95.6	.9 F1
3.0	117.8	27.8	93.7	.8 F1
3.5	124.9	31.3	92.2	.7 F1
4.0	131.0	34.4	91.0	.7 F1
4.5	136.2	37.2	90.1	.7 F1
5.0	140.7	39.7	89.6	.6 F1
5.5	144.4	41.8	89.4	.6 F1
6.0	147.5	43.6	89.5	.6 F1
6.5	149.9	45.1	89.9	.6 F1
7.0	151.8	46.2	90.7	.6 F1
7.5	153.1	47.0	91.8	.6 F1
8.0	153.9	47.5	93.3	.6 F1
8.5	154.1	47.6	95.1	.6 F1
9.0	153.8	47.4	97.2	.6 F1
9.5	152.9	46.9	99.7	.7 F1
10.0	151.5	46.0	102.5	.7 F1
10.5	149.5	44.8	105.6	.7 F1
11.0	146.9	43.3	109.0	.7 F1
11.5	143.7	41.4	112.8	.8 F1
12.0	139.8	39.2	117.0	.8 F1
12.5	135.2	36.7	121.4	.9 F1
13.0	129.8	33.8	126.2	1.0 F1
13.5	123.5	30.6	131.3	1.1 F1
14.0	116.2	27.1	136.8	1.2 F1
14.5	107.6	23.2	92.6	.9 F1
15.0	97.4	19.0	73.7	.8 F1
15.5	84.9	14.5	30.1	.4 F1
16.0	69.2	9.6	71.9	1.0 F1
16.5	46.8	4.4	94.1	2.0 F1

PATH STUDIED AT F = .9250 GHZ

EARTH K FACTOR

1.3333

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR RATIO
0.0	0.0	0.0	100.0	R F1
.5	52.2	4.1	102.8	2.0 F1
1.0	72.7	8.0	105.9	1.5 F1
1.5	87.6	11.6	104.2	1.2 F1
2.0	99.5	14.9	102.8	1.0 F1
2.5	109.4	18.0	101.6	.9 F1
3.0	117.8	20.9	100.7	.9 F1
3.5	124.9	23.5	100.0	.8 F1
4.0	131.0	25.8	99.6	.8 F1
4.5	136.2	27.9	99.4	.7 F1
5.0	140.7	29.8	99.5	.7 F1
5.5	144.4	31.4	99.8	.7 F1
6.0	147.5	32.7	100.4	.7 F1
6.5	149.9	33.8	101.2	.7 F1
7.0	151.8	34.7	102.3	.7 F1
7.5	153.1	35.3	103.6	.7 F1
8.0	153.9	35.6	105.2	.7 F1
8.5	154.1	35.7	107.0	.7 F1
9.0	153.8	35.6	109.1	.7 F1
9.5	152.9	35.2	111.4	.7 F1
10.0	151.5	34.5	114.0	.8 F1
10.5	149.5	33.6	116.8	.8 F1
11.0	146.9	32.5	119.9	.8 F1
11.5	143.7	31.1	123.2	.9 F1
12.0	139.8	29.4	126.8	.9 F1
12.5	135.2	27.5	130.6	1.0 F1
13.0	129.8	25.4	134.6	1.0 F1
13.5	123.5	23.0	139.0	1.1 F1
14.0	116.2	20.3	143.5	1.2 F1
14.5	107.6	17.4	98.4	.9 F1
15.0	97.4	14.3	78.4	.8 F1
15.5	84.9	10.9	33.8	.4 F1
16.0	69.2	7.2	74.3	1.1 F1
16.5	46.8	3.3	95.2	2.0 F1

PATH STUDIED AT F = .9250 GHZ

EARTH K FACTOR

INFINITY

D1 IN MILES	F1 IN FT.	HE IN FT.	CL IN FT.	CLR. RATIO
0.0	0.0	0.0	100.0	R F1
.5	52.2	0.0	106.9	2.0 F1
1.0	72.7	0.0	113.8	1.6 F1
1.5	87.6	0.0	115.8	1.3 F1
2.0	99.5	0.0	117.7	1.2 F1
2.5	109.4	0.0	119.6	1.1 F1
3.0	117.8	0.0	121.5	1.0 F1
3.5	124.9	0.0	123.5	1.0 F1
4.0	131.0	0.0	125.4	1.0 F1
4.5	136.2	0.0	127.3	.9 F1
5.0	140.7	0.0	129.2	.9 F1
5.5	144.4	0.0	131.2	.9 F1
6.0	147.5	0.0	133.1	.9 F1
6.5	149.9	0.0	135.0	.9 F1
7.0	151.8	0.0	136.9	.9 F1
7.5	153.1	0.0	138.8	.9 F1
8.0	153.9	0.0	140.8	.9 F1
8.5	154.1	0.0	142.7	.9 F1
9.0	153.8	0.0	144.6	.9 F1
9.5	152.9	0.0	146.5	1.0 F1
10.0	151.5	0.0	148.5	1.0 F1
10.5	149.5	0.0	150.4	1.0 F1
11.0	146.9	0.0	152.3	1.0 F1
11.5	143.7	0.0	154.2	1.1 F1
12.0	139.8	0.0	156.2	1.1 F1
12.5	135.2	0.0	158.1	1.2 F1
13.0	129.8	0.0	160.0	1.2 F1
13.5	123.5	0.0	161.9	1.3 F1
14.0	116.2	0.0	163.8	1.4 F1
14.5	107.6	0.0	115.8	1.1 F1
15.0	97.4	0.0	92.7	1.0 F1
15.5	84.9	0.0	44.6	.5 F1
16.0	69.2	0.0	81.5	1.2 F1
16.5	46.8	0.0	98.5	2.1 F1

```
      AEBIADQ.   76/12/08.  NOS 1.1 CONCORDIA UNIVERSITY.

08.23.33.NADER,CM60000,T20. EXPR
08.23.33.ACCOUNT,D740004,.
08.23.33.FTN.
08.23.35.      .708 CP SECONDS COMPILATION TIME
08.23.35.ATTACH,IMSLIB/UN=LIBRARY.
08.23.36.LDSET(LIB=IMSLIB)
08.23.36.LGO.
08.23.39.     STOP
08.23.39.     1.602 CP SECONDS EXECUTION TIME
08.23.39.UEPF,      0.009KUNS.
08.23.39.UEMS,      0.506KUNS.
08.23.39.UECP,      3.077SECS.
08.23.39.AESR,      3.478UNTS.
```

FIG. 1 - FORMAT (4X, F 9.4)

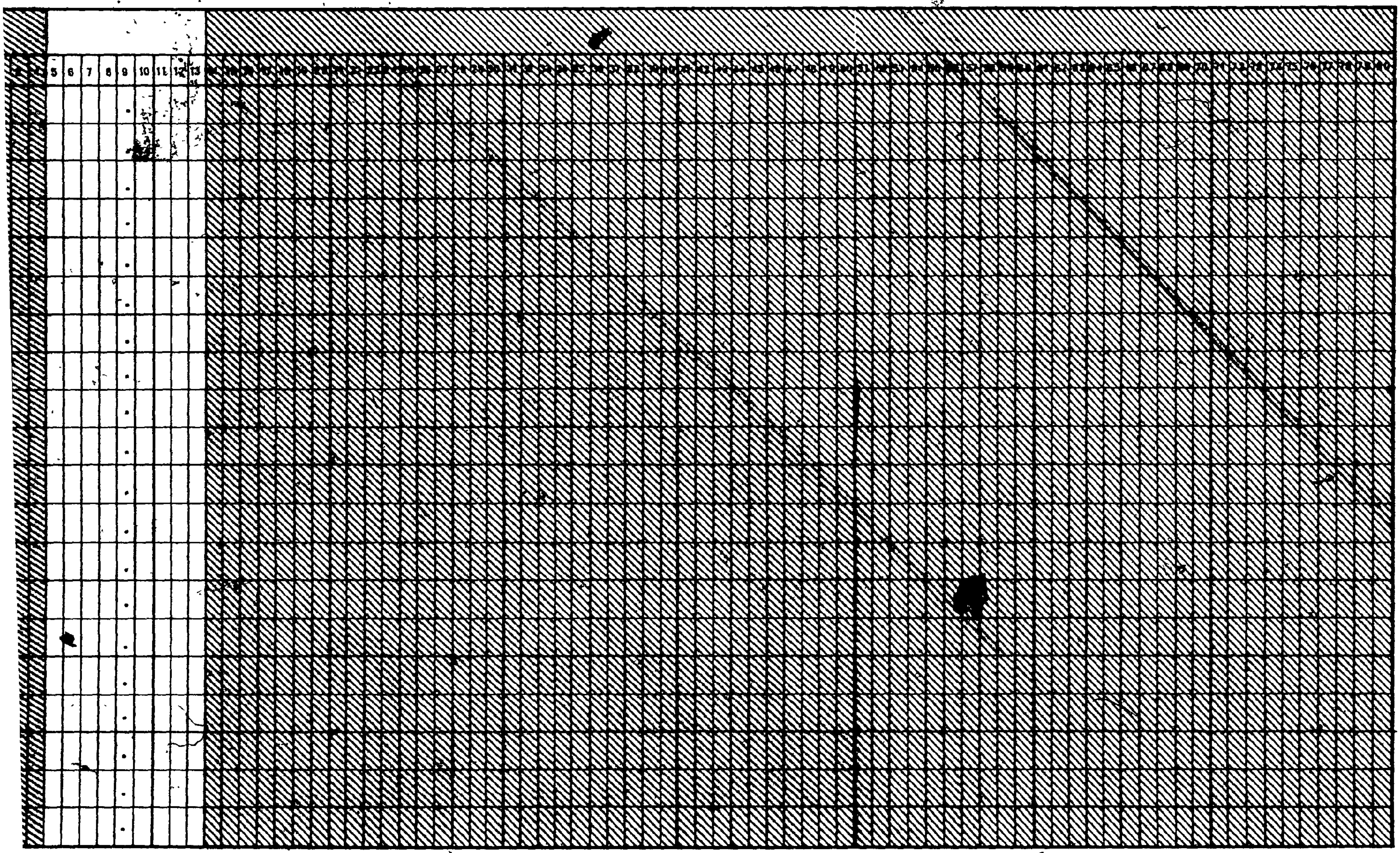
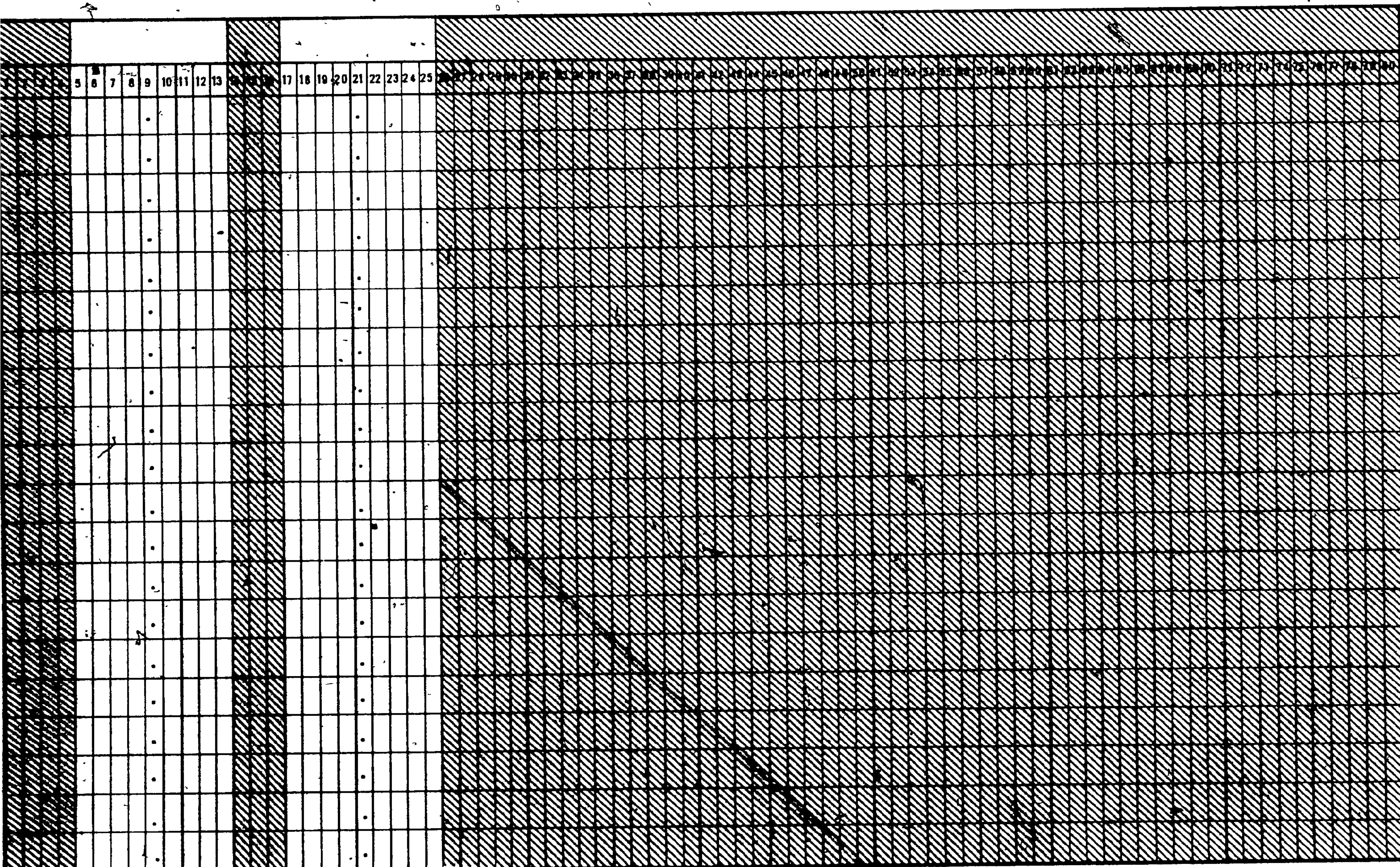


FIG. 2 - FORMAT (1X, 2(3X, F 9.4))



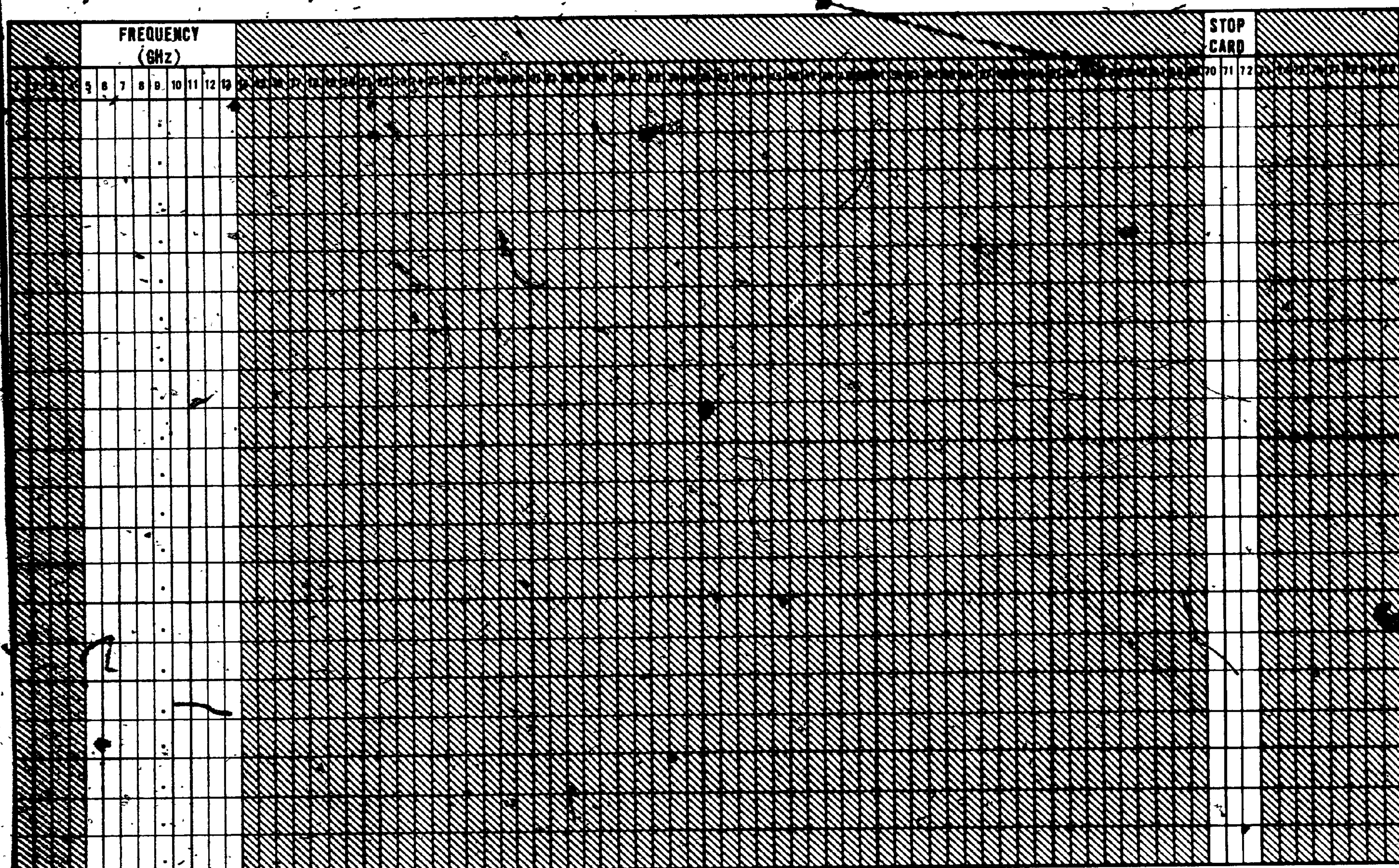


FIG. 3 - FORMAT (4X, F 9.4, T70, I3)

SHEET (1)

FIG. 4 – INPUT DATA CARDS FOR THE ENCLOSED EXAMPLE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	CARD NUMBER
						1	8	.	9																																																																	1
						1	0	.	0									7	5	.	0																																																						2
					1	0	0	.	0								1	0	0	.	0																																																						3
						1	0	.	0																																																																	4
							5	.	0																																																																	5
							0	.	0																																																																	6
							0	.	0																																																																	7
							0	.	0																																																																	8
							0	.	0																																																																	9
							0	.	0																																																																	10
							0	.	0																																																																	11
							0	.	0																																																																	12
							0	.	0																																																																	13
							0	.	0																																																																	14
							0	.	0																																																																	15
							0	.	0																																																																	16
							0	.	0																																																																	17
							0	.	0																																																																	18
							0	.	0																																																																	19
							0	.	0																																																																	20

SHEET (2)

FIG. 4 – INPUT DATA CARDS FOR THE ENCLOSED EXAMPLE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	CARD NUMBER
							0	.	0																																																																				21
							0	.	0																																																																			22
							0	.	0																																																																			23
							0	.	0																																																																			24
							0	.	0																																																																			25
							0	.	0																																																																			26
							0	.	0																																																																			27
							0	.	0																																																																			28
							0	.	0																																																																			29
							0	.	0																																																																			30
							0	.	0																																																																			31
							0	.	0																																																																			32
						5	0	.																																																																				33
						7	5	.																																																																				34
						2	5	.																																																																				35
						9	0	.																																																																				36
						7	5	.																																																																				37
							7	.	1	2	5																																																																	38
							1	.	9																																																																			39
								.	9	2	5																																																					9	9	9				40

APPENDIX C

CONTENTS FOR APPENDIX C

FIGURES AND SAMPLES

C1.0 INTRODUCTION

Program "P.T.P.R.S." (Point-to-Point Radio System) was developed to provide a detailed analysis for the performance of any point-to-point Radio system. The main purpose of having this program is to provide all the required data requested by the Department of Communication (D.O.C.) in Canada when writing an Engineering Brief.

This program was developed according to the D.O.C. regulations at the time of writing this manual. Caution should be taken, whenever used, to make sure that all conditions are still applicable.

This program can examine the same site performance for indefinite number of cases. Each case will represent the usage of a different combination of antennae gains. Flow Chart for Program P.T.P.R.S. and a complete Program print-out is shown at the end of this Appendix.

C2.0 COMPUTER LANGUAGE

The language used in Fortran IV punched on cards using BCD format (026). It should be noted that there are references to logarithmic functions in this program. Some computers store these functions, i.e. in the LIBRARY. When used aa a reference to the LIBRARY, it should be made in the compilation cards.

C3.0 INPUT AND OUTPUT DATA

The required INPUT data for this program is listed below in order, as read by the computer:

1. Distance (Miles) and Carrier Frequency (GHz).
2. Reliability Computation Factors A and B.

3. Transmitter Power Output at Station (1), and at Station (2) (dBm).

4. Transmission Line Loss at Station (1), and at Station (2) (dB/100 ft at the carrier frequency).

5. Transmission Line Length at Station (1), and at Station (2) (ft).

6. Duplexer Losses at Station (1), and at Station (2) (dB).

7. Fitting Losses at Station (1), and at Station (2) (dB).

8. Receiver Squelch Level (dBm), and Receiver Noise Figure (dB).

9. Transmitter I.F. Bandwidth (KHz), Baseband (KHz), r.m.s. per channel deviation (KHz), number of (3.1 KHz) voice channels, and maximum allowable Effective Isotropical Radiated Power (dBW).

10. Extra Attenuation due to: Atmospheric, absorbation, obstruction, etc. (dB).

11. Antennae gains at Station (1), and at Station (2) (dBI).

C3.1 FORMAT FOR THE INPUT DATA

- The used format for (1) to (8) in Section C3.0 is as follows:

  (1X, 2 (3X, F9.4))

  See Fig. 1.

- The used format for (9) in Section C3.0 is as follows:

  (1X, 5 (2X, F 10.4))

  See Fig. 2

- The used format for (10) in Section C3.0 is as follows:

  (4X, F 9.4, 1)

  See Fig. 3.

A blank data card is inserted between the antennae gains data cards and the previous (1) to (10) cards. This to help identifying the first antennae data card.

- The used format for (11) in Section C3.0 is as follows:

    (1X, 2 (3X, F9.4), T70, 13)

    See Fig. 4.

The computed OUTPUT(s) are as follows:

1. The necessary Bandwidth for transmission (kHz).
2. For each combination of antennae:
    a) Path loss (dB).
    b) Fade margin (dB).
    c) Median received signal and received signal at each end (dBm and microvolts).
    d) Effective isotropic radiated power at each end (dBW).
    e) Rayleigh unavailability, and availability (%).
    f). Actual unavailability, and availability (%).
    g) Signal to noise ratio (dB), and the equivalent weighted values in dBrnc0, dBA0, dBm0p, Pwp0.

NOTES:

1. Programs "AZIM" and "CLEAR" should be used to obtain the following data:
    a) Exact distance between station (1) and station (2).
    b) Adequacy of the clearance of the radio beam for this path.
    c) The necessary tower height at each end to satisfy (b) above.
    d) The carrier frequency that will be used.

C3.2 EXAMPLE:

The performance of a Point-to-Point Radio System is to be examined using the following data:

1. Distance = 16.9 miles

   Frequency = 0.95 GHz

2. Overwater Path - Roughness Factor - A = 4

   Factor to Convert worst month probability to annual probability - B = 1/2.

3. Transmitter output TXP1 = TXP2 = 38.8 dBm.

4. Transmission line loss C1 = C2 = 1.9 dB/100 ft.

5. Transmission line length TL1 = TL2 = 200 ft.

6. Duplexer loss DUL1 = DUL2 = 2.0 dB

7. Fittings Losses FIT1 = FIT2 = 1.0 dB.

8. Receiver Squelch level = 89.0 dBm

   Receiver noise figure = 9.0 dB

9. Transmitter:

   a) I.f bandwidth = 2700 kHz

   b) Baseband = 124.0 kHz

   c) r.m.s. per channel deviation = $\pm$ 35.0 kHz

   d) Number of (3.1 kHz) Channels = 24 channel

   e) Max. allowable EIRP = 35.0 kBW

10. Extra attention due to not having full clearance = 4.1 dB

11. Antenna gains:

    Case (a) Station (1): 22.0 dBI, Station (2): 22.0 dBI

    (b) Station (1): 28.0 dBI, Station (2): 28.0 dBI

    (c) Station (1): 33.0 dBI, Station (2): 33.0 dBI

(d) Station (1): 36.5 dBI, Station (2): 36.5 dBI

(e) Station (1): 40.0 dBI, Station (2): 40.0 dBI

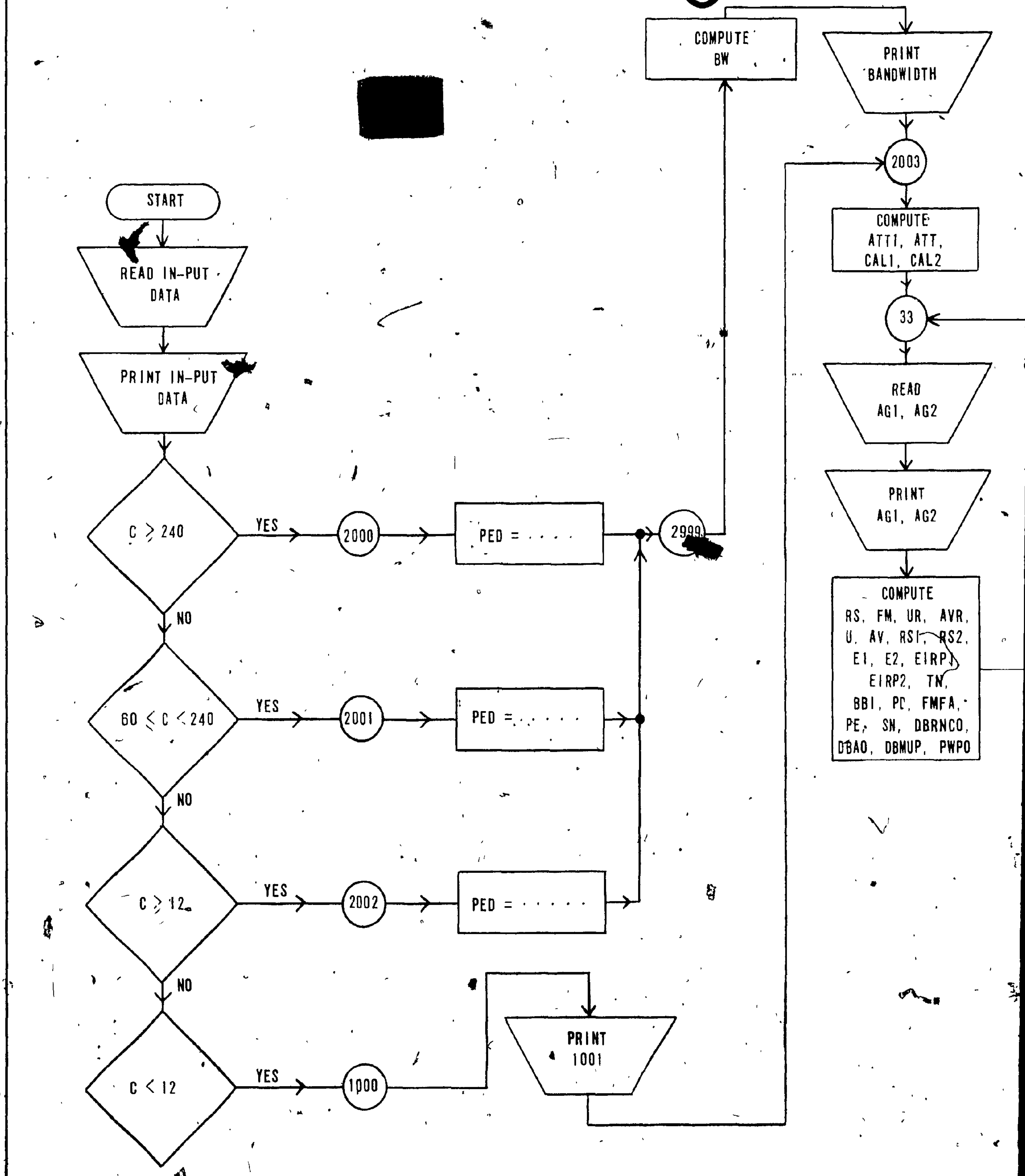
(f) Station (1): 42.5 dBI, Station (2): 42.5 dBI

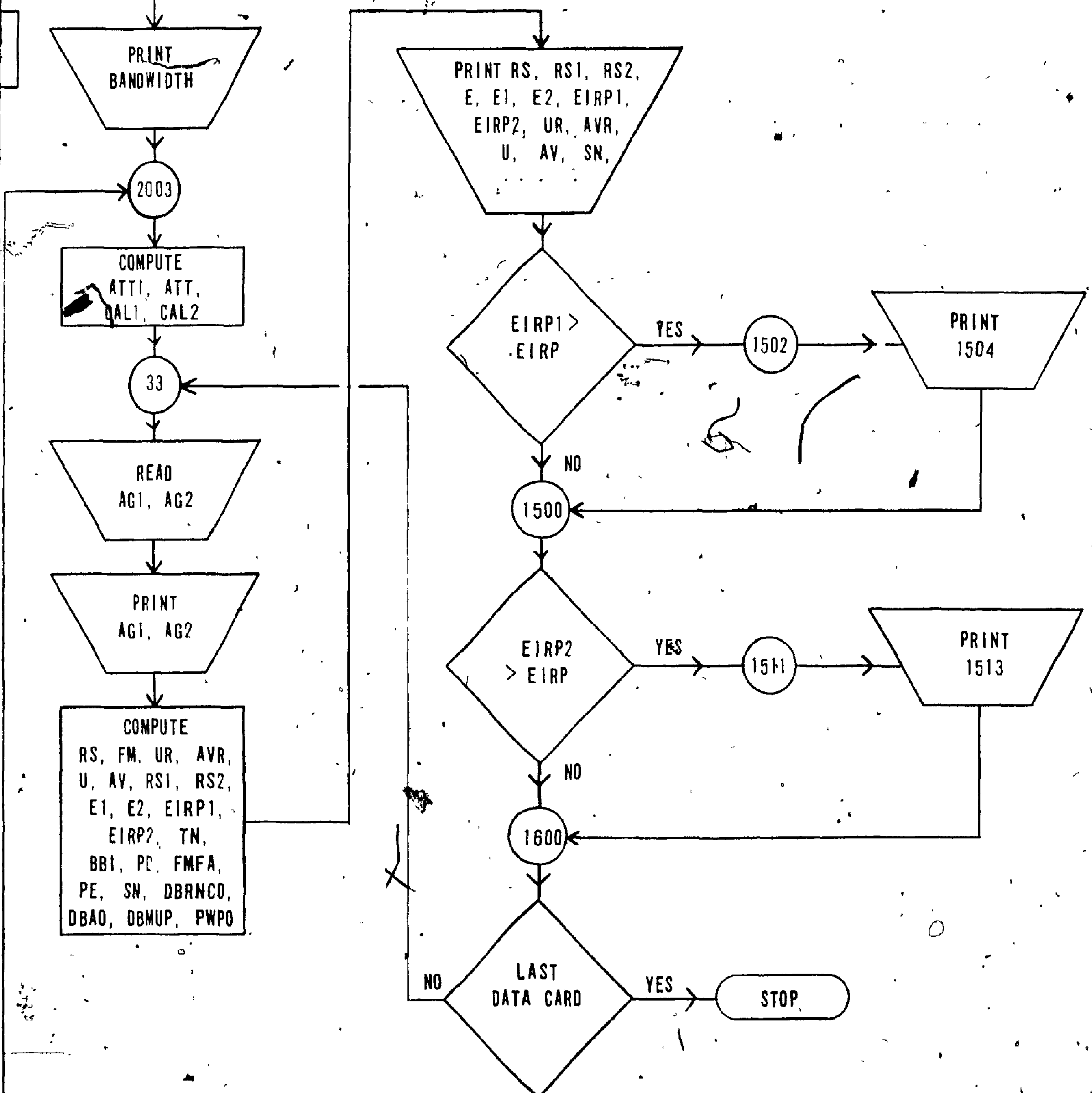
(See fig. 5 for details).

<u>Output records:</u>

See complete print-out.

montreal engineering comp





PROGRAM P.T.P.R.S. FLOW CHART

```
C     THIS PROGRAM IS TO COMPUTE THE MEDIAN RECEIVED SIGNAL,RECEIVED
C      SIGNAL AND THE EFFECTIVE ISOTROPICAL RADIATED POWER AT EACH END ,
C      FADE MARGIN ,RAYLEIGH PROBABILITY,ACTUAL PROBABILITY OF OUTAGE ,
C      SIGNAL TO NOISE RATIO,AND THE NECESSARY BAND WIDTH
C     FOR ANY POINT TO POINT RADIO SYSTEM WITH LINE OF SITE PATH AND ADEQUATE
C      FRESNEL ZONE CLEARANCE EVERYWHERE.
C     THE UNITS OF THE USED PARAMETERS ARE AS FOLLOWS"
C           D=DISTANCE IN MILES.
C           F=FREQUENCY IN GEGAHERTZ.
C           A=ROUGHNESS FACTOR.
C           B=FACTOR TO CONVERT WORST MONTH PROBABILITY TO ANNUAL PROB.
C           FM=FADE MARGIN IN DB.
C           UR=RAYLEIGH FADE PROBABILITY.
C           AVR=RAYLEIGH AVAILABILITY PER CENT.
C           U=ACTUAL FADE PROBABILITY.
C           AV=AVAILABILITY PER CENT.
C           ATT=TOTAL PATH PROPAGATION LOSS.
C           ATT1=FREE SPACE ATTINUATION BETWEEN ISOTROPIC ANTENNAE.
C           ATT2=ADDITIONAL ATTINUATION DUE TO NOT HAVING FULL CLEARANCE+
C                  ATTENUATION DUE TO ATMOSPHERIC ABSORBATION.
C           TXP1=TRANSMITTER OUTPUT POWER AT STATION 1 IN DBM.
C           TXP2=TRANSMITTER OUTPUT POWER AT STATION 2 IN DBM.
C           RCS=RECEIVER SQUELCH LEVEL IN DBM.
C           RN=RECEIVER NOISE FIGURE IN DB.
C           AG1=ANTENNA GAIN AT STATION 1 IN DBI.
C           AG2=ANTENNA GAIN AT STATION 2 IN DBI.
C           C1=TRANSMISSION LINE LOSS AT STATION 1 IN DB/100. FT.
C           C2=TRANSMISSION LINE LOSS AT STATION 2 IN DB/100. FT.
C           TL1=TRANSMISSION LINE LENGTH AT STATION 1 IN FT.
C           TL2=TRANSMISSION LINE LENGTH AT STATION 2 IN FT.
C           DUL1=DUPLEXER LOSS AT STATION 1 IN DB.
C           DUL2=DUPLEXER LOSS AT STATION 2 IN DB.
C           FIL1=FITTINGS LOSS AT STATION 1 IN DB.
C           FIL2=FITTINGS LOSS AT STATION 2 IN DB.
C           RS=MEDIAN RECEIVED SIGNAL IN DBM,=E IN MICROVOLTS.
C           RS1=RECEIVED SIGNAL AT STATION 1 IN DBM,=E1 IN MICROVOLTS.
C           RS2=RECEIVED SIGNAL AT STATION 2 IN DBM,=E2 IN MICROVOLTS.
C           EIRP1=EFFECTIVE ISOTROPICAL RADIATED POWER AT STATION 1 IN DBW.
C           EIRP2=EFFECTIVE ISOTROPICAL RADIATED POWER AT STATION 2 IN DBW.
C           FIFB=I.F BAND WIDTH IN KHZ.
C           BB=BASEBAND IN KHZ.
C           DEV=R.M.S PER CHANNEL DEVIATION IN KHZ.
C           C=NUMBER OF (3.1 KHZ) VOICE CHANNELS.
C           S/N=SIGNAL TO NOISE RATIO.
C           BW=NECESSARY BANDWIDTH IN KHZ.
      PROGRAM PTPRS (INPUT,OUTPUT)
      READ 1,D,F
      READ 1,A,B
      READ 1,TXP1,TXP2
      READ 1,C1,C2
      READ 1,TL1,TL2
      READ 1,DUL1,DUL2
      READ 1,FIL1,FIL2
```

```
      READ 1,RCS,RN
      READ 2,FIFB,BB,DEV,C,EIRP
      READ 3,ATT2
      PRINT  5,D,F
      PRINT  6,A,B
      PRINT  7,TXP1,TXP2
      PRINT  8,C1,C2
      PRINT  9,TL1,TL2
      PRINT 15,DUL1,DUL2
      PRINT 16,FIL1,FIL2
      PRINT 17,RCS,RN
      PRINT 18,FIFB,BB,DEV,C,EIRP
      PRINT 13,ATT2
    1 FORMAT (1X,2(3X,F9.4))
    2 FORMAT (1X,5(2X,F10.4))
    3 FORMAT (4X,F9.4,/)
    4 FORMAT (1X,2(3X,F9.4),T70,I3)
    5 FORMAT (1H1,//,T7,*IN-PUT DATA*,/,T7,*-------------*,/,T7,*D =*,
     1F9.4,T41,*F =*,F9.4)
    6 FORMAT (//,T7,*A =*,F9.4,T41,*B =*,F9.4)
    7 FORMAT (//,T7,*TXP1 =*,F9.4,T41,*TXP2 =*,F9.4)
    8 FORMAT (//,T7,*C1    =*,F9.4,T41,*C2    =*,F9.4)
    9 FORMAT (//,T7,*TL1   =*,F9.4,T41,*TL2   =*,F9.4)
   10 FORMAT (//,T7,*SYSTEM PERFORMANCE-*,/,
     1T7,*ATT=*,F9.4,T37,*FM=*,F9.4,//)
   11 FORMAT (1H1,T7,*   AG1     *,T18,*    AG2     *,/,
     1T7,*----------*,T18,*----------*,)
   13 FORMAT (//,T7,*ATT2 =*,F9.4)
   15 FORMAT (//,T7,*DUL1 =*,F9.4,T41,*DUL2 =*,F9.4)
   16 FORMAT (//,T7,*FIL1 =*,F9.4,T41,*FIL2 =*,F9.4)
   17 FORMAT (//,T7,*RCS  =*,F9.4,T41,*RN   =*,F9.4)
   18 FORMAT (//,T7,*FIFB =*,F10.4,T30,*BB =*,F10.4,T52,*DEV =*,F10.4,
     1T75,*C =*,F10.4,T97,*EIRP =*,F10.4)
   20 FORMAT (/,T7,*RS=*,F9.4,T37,*RS1=*,F9.4,T67,*RS2=*,F9.4,//)
   21 FORMAT (/,T7,*E =*,F9.1,T37,*E1 =*,F9.1,T67,*E2 =*,F9.1,//)
   30 FORMAT (/,T7,*EIRP1=*,F9.4,T37,*EIRP2=*,F9.4,//)
   40 FORMAT (/,T7,*UR=*,E15.8,T37,*AVR=*,E15.8,//
     1T7,*U=*,E15.8,T37,*AV=*,E15.8,//)
   50 FORMAT (/,T7,*S/N=*,F9.4,* DB*,T30,*=*,F9.4,* DBRNC0*,T52,*=*,F9.4,
     1* DBA0*,T75,*=*,F9.4,* DBM0P*,T97,*=*,F9.4,* PWP0*,//)
   60 FORMAT (////,T7,*NECESSARY BANDWIDTH = *,F9.4,* KHZ*,)
 1001 FORMAT (/,T7,*C IS LESS THAN 12 CHANNELS *,/,
     1T7,*MORE DATA IS REQUIRED TO CALCULATE THE BW.*,)
 1504 FORMAT (//,T39,*----A L A R M----*,/,
     1T23,*EIRP1 EXCEEDED MAX. ALLOWABLE EIRP YOU GAVE ME *,/,
     2T30,*YOU CAN NOT GET AWAY WITH THAT*,/,
     3T28,*THE D. O. C WILL JUMP ON YOU FOR THAT*,//)
 1513 FORMAT (//,T39,*----A L A R M----*,/,
     1T20,*EIRP2 EXCEEDED THE MAX. ALLOWABLE EIRP YOU GAVE ME*,/,
     2T30,*YOU CAN NOT GET AWAY WITH THAT*,/,
     3T28,*THE D. O. C WILL GET YOU FOR THAT*,//)
      IF (C.GE.240.) GO TO 2000
      IF (C.GE.60..AND.C.LT.240.) GO TO 2001
```

```
      IF (C.GE.12..AND.C.LT.60.) GO TO 2002
      IF (C.LT.12.) GO TO 1000
      GO TO 2003
 2000 PED=DEV*3.76*10.**((-15.+10.*ALOG10(C))/20.)
      GO TO 2999
 2001 PED=DEV*3.76*10.**((-1.+4.*ALOG10(C))/20.)
      GO TO 2999
 2002 PED=DEV*3.76*10.**((2.6+2.*ALOG10(C))/20.)
 2999 BW=2.*(BB+0.9*PED)
      PRINT 60,BW
 2003 CONTINUE
      ATT1=(96.6+20.*ALOG10(F)+20.*ALOG10(D))
      ATT=ATT1+ATT2
      CAL1=(C1*TL1)/100.
      CAL2=(C2*TL2)/100.
   33 READ 4,AG1,AG2,N
      PRINT 11
      PRINT 1,AG1,AG2
      RS=AG1+AG2+((TXP1+TXP2)/2.)-CAL1-CAL2-DUL1-DUL2-FIL1-FIL2-ATT
      FM=-RCS+RS
      UR=10.**(-0.1*FM)
      AVR=100.*(1.-UR)
      U=A*B*2.5*F*D*D*D*UR*10.**(-6.)
      AV=100.*(1.-U)
      RS1=AG1+AG2+TXP2-CAL1-CAL2-DUL1-DUL2-FIL1-FIL2-ATT
      RS2=AG1+AG2+TXP1-CAL1-CAL2-DUL1-DUL2-FIL1-FIL2-ATT
      E=SQRT(50.*10.**((RS+90.)/10.))
      E1=SQRT(50.*10.**((RS1+90.)/10.))
      E2=SQRT(50.*10.**((RS2+90.)/10.))
      EIRP1=AG1+TXP1-CAL1-DUL1-FIL1-30.
      EIRP2=AG2+TXP2-CAL2-DUL2-FIL2-30.
      TN=RN+10.*ALOG10(FIFB)-104.-30.0
      BB1=10.*ALOG10(FIFB/6.2)
      PD=DEV*SQRT(2.)
      FMFA=20.*ALOG10(PD/BB)
      PE=3.7
      SN= RS-TN+BB1+FMFA+PE
      DBRNCO=88.-SN
      DBAO=DBRNCO-6.
      DBMOP=DBRNCO-90.
      PWPO=10.**(0.1*DBRNCO)
      PRINT 10,ATT,FM
      PRINT 20,RS,RS1,RS2
      PRINT 21,E,E1,E2
      PRINT 30,EIRP1,EIRP2
      PRINT 40,UR,AVR,U,AV
      PRINT 50,SN,DBRNCO,DBAO,DBMOP,PWPO
      IF (EIRP1.GT.EIRP) GO TO 1502
 1500 CONTINUE
      IF (EIRP2.GT.EIRP) GO TO 1511
 1600 CONTINUE
      IF (N.EQ.999) STOP
      GO TO 33
```

```
  160         1000 PRINT 1001
                   GO TO 2003
              1502 PRINT 1504
                   GO TO 1500
              1511 PRINT 1513
  165              GO TO 1600
                   END
```

SYMBOLIC REFERENCE MAP (R=1)

```
ENTRY POINTS
 4112  PTPRS

VARIABLES      SN  TYPE          RELOCATION
 5262  A           REAL                          5314  AG1       REAL
 5315  AG2         REAL                          5311  ATT       REAL
 5310  ATT1        REAL                          5305  ATT2      REAL
 5324  AV          REAL                          5322  AVR       REAL
 5263  B           REAL                          5301  BB        REAL
 5335  BB1         REAL                          5307  BN        REAL
 5303  C           REAL                          5312  CAL1      REAL
 5313  CAL2        REAL                          5266  C1        REAL
 5267  C2          REAL                          5260  D         REAL
 5343  DBAO        REAL                          5344  DBMOP     REAL
 5342  DBRNCU      REAL                          5302  DEV       REAL
 5272  DUL1        REAL                          5273  DUL2      REAL
 5327  E           REAL                          5304  EIRP      REAL
 5332  EIRP1       REAL                          5333  EIRP2     REAL
 5330  E1          REAL                          5331  E2        REAL
 5261  F           REAL                          5300  FIFB      REAL
 5274  FIL1        REAL                          5275  FIL2      REAL
 5320  FM          REAL                          5337  FMFA      REAL
 5316  N           INTEGER                       5336  PO        REAL
 5340  PE          REAL                          5306  PED       REAL
 5345  PMPO        REAL                          5276  RCS       REAL
 5277  RN          REAL                          5317  RS        REAL
 5325  RS1         REAL                          5326  RS2       REAL
 5341  SN          REAL                          5270  TL1       REAL
 5271  TL2         REAL                          5334  TN        REAL
 5264  TXP1        REAL                          5265  TXP2      REAL
 5323  U           REAL                          5321  UR        REAL

FILE NAMES          MODE
   0  INPUT         FMT          2043  OUTPUT      FMT

EXTERNALS           TYPE    ARGS
      ALOG10        REAL     1 LIBRARY             SQRT       REAL       1 LIBRARY
```

```
STATEMENT LABELS
  4634  1     FMT          4637  2     FMT          4642  3     FMT
  4644  4     FMT          4647  5     FMT          4660  6     FMT
  4665  7     FMT          4672  8     FMT          4677  9     FMT
  4704  10    FMT          4714  11    FMT          4724  13    FMT
  4730  15    FMT          4735  16    FMT          4742  17    FMT
  4747  18    FMT          4762  20    FMT          4771  21    FMT
  5000  30    FMT          4242  33                 5006  40    FMT
  5017  50    FMT          5035  60    FMT          4440  1000
  5043  1001  FMT          4432  1500               4443  1502
  5055  1504  FMT          4446  1511               5077  1513  FMT
  4434  1600               4172  2000               4202  2001
  4212  2002               4225  2003               4220  2999

STATISTICS
   PROGRAM LENGTH          1240B    672
   BUFFER LENGTH           4106B    2118
```

INPUT DATA

D = 16.9000   F = .9250

A = 4.0000   B = .5000

TXP1 = 38.8000   TXP2 = 38.8000

C1 = 1.9000   C2 = 1.9000

TL1 = 200.0000   TL2 = 200.0000

DUL1 = 2.0000   DUL2 = 2.0000

FIL1 = 1.0000   FIL2 = 1.0000

RCS = -89.0000   RN = 9.0000

FIFB = 2700.0000   BB = 124.0000   UEV = 35.0000   C = 24.0000   EIRP = 35.0000

ATT2 = 4.1000

NECESSARY BANDWIDTH = 687.0659 KHZ

```
AG1         AG2
---------   ---------
22.0000     22.0000

SYSTEM PERFORMANCE-
ATT= 124.5806              FM=  33.6194

RS= -55.3806               RS1= -55.3806               RS2= -55.3806

E =    380.6               E1 =    380.6               E2 =    380.6

EIRP1=  24.0000            EIRP2=  24.0000

UR=  .43456713E-03         AVR=  .99956543E+02
U=  .97012730E-05          AV=  .99999030E+02

S/N=  57.4187 DB     =  30.5813 DBRNCO     =  24.5813 DBAU     = -59.4187 DBNOP     =1143.2096 PWPO
```

```
  AG1        AG2
---------  ---------
 28.0000    28.0000

SYSTEM PERFORMANCE=
ATT= 128.5806            FM= 45.6194

RS= -43.3806             RS1= -43.3806             RS2= -43.3806

E =  1515.2              E1 =  1515.2              E2 = 1515.2

EIRP1= 30.0000           EIRP2= 30.0000

UR= .27419532E-04        AVR= .99997258E+02
U= .61210894E-06         AV= .99999939E+02

S/N= 69.4187 DB     = 10.5813 DBRNCO     = 12.5813 DBAO     = -71.4187 DBMOP     = 72.1316 PWPO
```

```
AG1          AG2
---------    ---------
33.0000      33.0000

SYSTEM PERFORMANCE-
ATT= 124.5806              FN=  55.6194

RS= -33.3806               RS1= -33.3806               RS2= -33.3806

E =   4791.3               E1 =  4791.3                E2 =   4791.3

EIRP1=  35.0000            EIRP2=  35.0000

UR=  .27419332E-05         AVN=  .99999720E+02
U=  .61210894E-07          AV=  .99999994E+02

S/N=  79.4187 DB      =  8.5813 DBRNC0     =  2.5813 DBAU        = -81.4187 DBMOP      =  7.2132 PWPU
```

```
   AG1        AG2
 --------   --------
 36.5000    36.5000

SYSTEM PERFORMANCE-
ATT= 128.5000              FM= 62.4194

RS= -20.3800               RS1= -20.3800            RS2= -20.3800

E =  10720.5               E1 =  10720.5            E2 =  10720.5

EIRP1=  38.5000            EIRP2=  38.5000

UR=  .54208768E-06         AVR=  .99999945E+02

U=  .12213179E-07          AV=  .99999999E+02

S/N=  86.4187 DB     =  1.5013 DBRNCO    =  -4.4187 DBAU     = -88.4187 DBMOP     =  1.4392 PWPO

                 ---A L A R M---
      EIRP1 EXCEEDED MAX. ALLOWABLE EIRP YOU GAVE ME
           YOU CAN NOT GET AWAY WITH THAT
         THE O. O. C WILL JUMP ON YOU FOR THAT

                 ---A L A R M---
     EIRP2 EXCEEDED THE MAX. ALLOWABLE EIRP YOU GAVE ME
           YOU CAN NOT GET AWAY WITH THAT
         THE O. O. C WILL GET YOU FOR THAT
```

```
AG1          AG2
********     ********
40.0000      40.0000

SYSTEM PERFORMANCE :
ATT= 124.5000                FM= 69.6194

RS= -19.3000                 RS1= -19.3000            RS2= -19.3000

E =  24013.6                 E1 = 24013.6             E2 = 24013.6

EIRP1=  42.0000              EIRP2=  42.0000

UR=  .10915833E-06           AVR=  .99999989E+02
U=  .24368496E-08            AV=  .10000000E+03

S/N=  93.4187 DB      =  -5.4187 DBMCO      = -11.4187 DBAU      = -95.4187 DBWOP      =   .2872 PWPO

          ***A L A R M***
EIRP1 EXCEEDED MAX. ALLOWABLE EIRP YOU GAVE ME
      YOU CAN NOT GET AWAY WITH THAT
    THE D. O. C WILL JUMP ON YOU FOR THAT

          ***A L A R M***
EIRP2 EXCEEDED THE MAX. ALLOWABLE EIRP YOU GAVE ME
      YOU CAN NOT GET AWAY WITH THAT
    THE D. O. C WILL GET YOU FOR THAT
```

```
   AG1          AG2
 --------     ---------
 40.0000      40.0000

SYSTEM PERFORMANCE=
ATT= 124.5000                FM= 69.6194

RS= -19.3000                 RS1= -19.3000              RS2= -19.3000

E = 24013.0                  E1 = 24013.0               E2 = 24013.0

EIRP1= 42.0000               EIRP2= 40.0000

UR= .10015033E-06            AVR= .99999989E+02
U= .24368496E-08             AV= .10000000E+03

S/N= 91.4187 DB       = -5.4187 DBRNCO     = -11.4187 DBAU       = -95.4187 DBMOP      =     .2872 PWPO

                 ***A L A R M***
     EIRP1 EXCEEDED MAX. ALLOWABLE EIRP YOU GAVE ME
            YOU CAN NOT GET AWAY WITH THAT
         THE O. D. C WILL JUMP ON YOU FOR THAT

                 ***A L A R M***
    EIRP2 EXCEEDED THE MAX. ALLOWABLE EIRP YOU GAVE ME
            YOU CAN NOT GET AWAY WITH THAT
           THE O. D. C WILL GET YOU FOR THAT
```

```
  AG1          AG2
---------    ---------
 42.5000      42.5000

SYSTEM PERFORMANCE-
ATT= 124.5000              FM=  74.6194

RS= -14.3000               RS1= -14.[illegible]            RS2= -14.3000

E =  42702.8               E1 =  42702.8                E2 =  42702.8

EIRP1=  44.5000            EIRP2=  44.5000

VR=  .38518894E-07         AVR=  .99999997E+02
V=  .77059950E-09          AV=  .10000000E+03

S/N=  90.4187 DB       = -10.4187 DBRNCO      = -16.4187 DBAO        =-100.4187 DBMOP        =    .0908 PWPO

                       ---A L A R M---
        EIRP1 EXCEEDED MAX. ALLOWABLE EIRP YOU GAVE ME
              YOU CAN NOT GET AWAY WITH THAT
            THE O. O. C WILL JUMP ON YOU FOR THAT

                       ---A L A R M---
      EIRP2 EXCEEDED THE MAX. ALLOWABLE EIRP YOU GAVE ME
              YOU CAN NOT GET AWAY WITH THAT
            THE O. O. C WILL GET YOU FOR THAT
```

```
AEGIADU.   76/12/08.  NOS 1.1 CONCORDIA UNIVERSITY.

08.27.40.NADER.CM60000,T20, EXPRESS.
08.27.41.ACCOUNT,D740000,.
08.27.41.FTN.
08.27.44.      1.579 CP SECONDS COMPILATION TIME
08.27.44.ATTACH,IMSLIB/UN=LIBRARY.
08.27.44.LDSET(LIB=IMSLIB)
08.27.44.LGO.
08.27.46.     STOP
08.27.46.       .209 CP SECONDS EXECUTION TIME
08.27.46.UEPF.      0.009KUNS.
08.27.46.UEMS.      0.510KUNS.
08.27.46.UECP.,     2.660SECS.
```

FIG. 1 - FORMAT (1 x, 2 (3 x, F9.4))

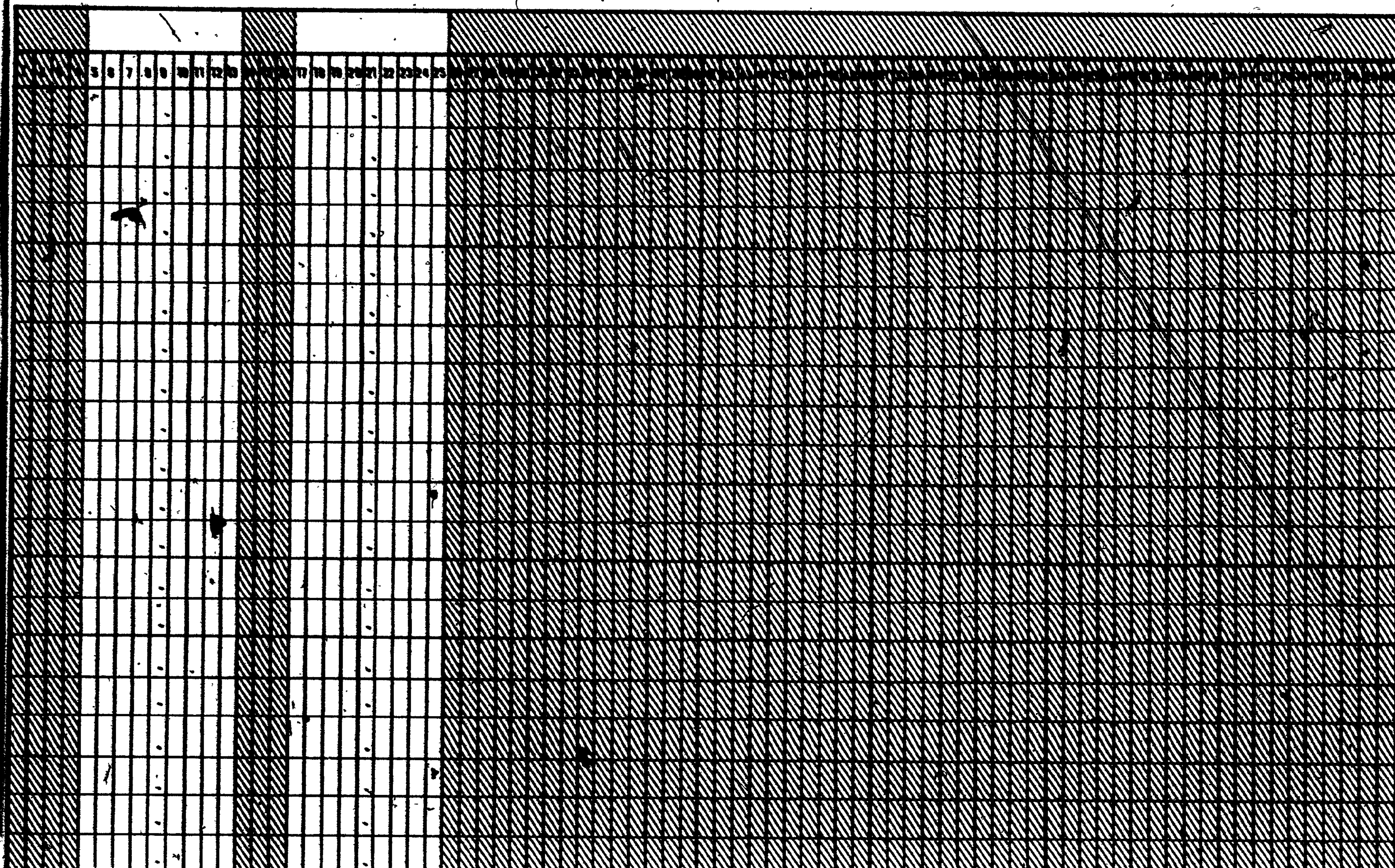


FIG. 2 - FORMAT (1 x, 5 (2 x, F10.4))

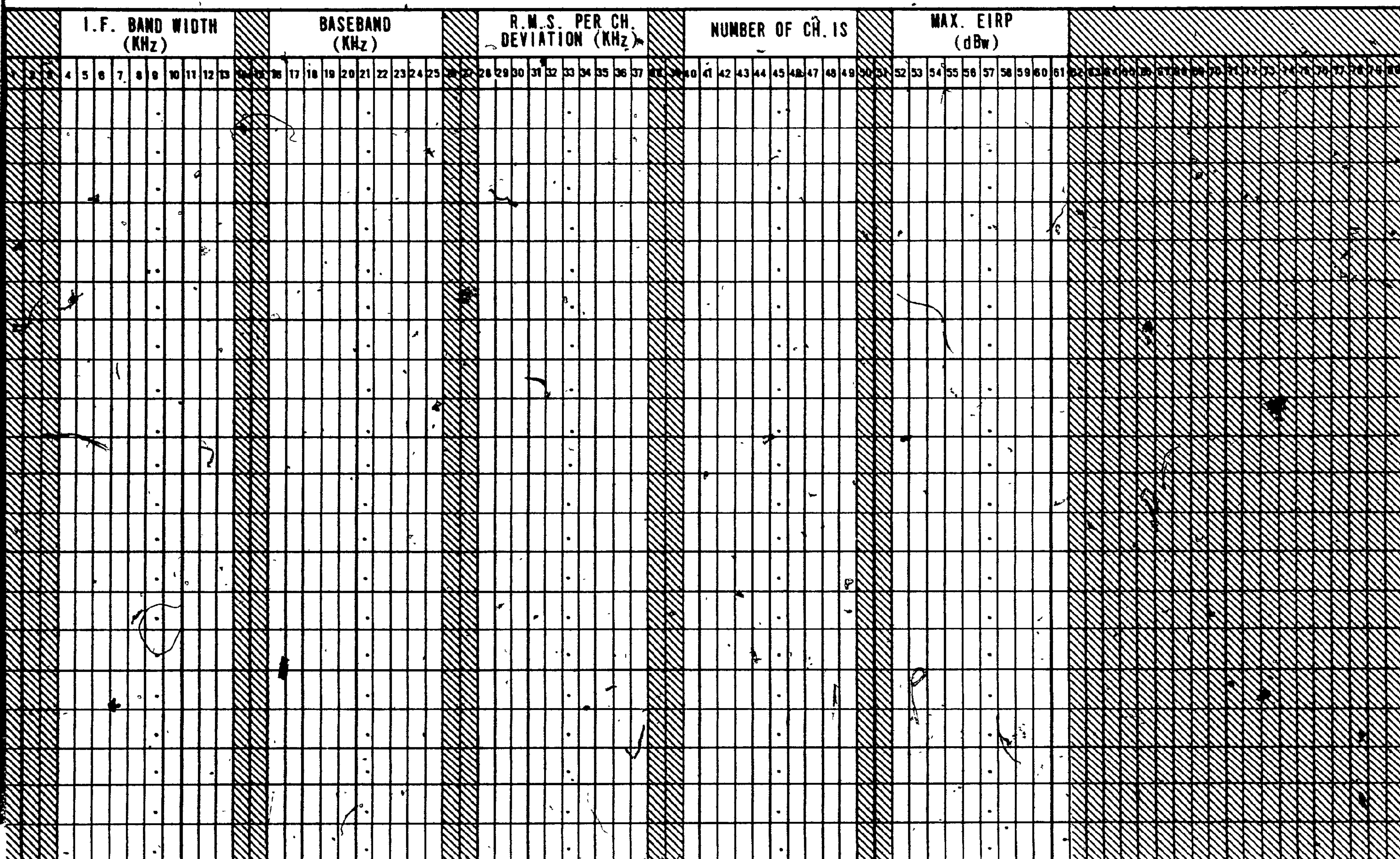


FIG. 3 - FORMAT (4 x, F9.4),/)

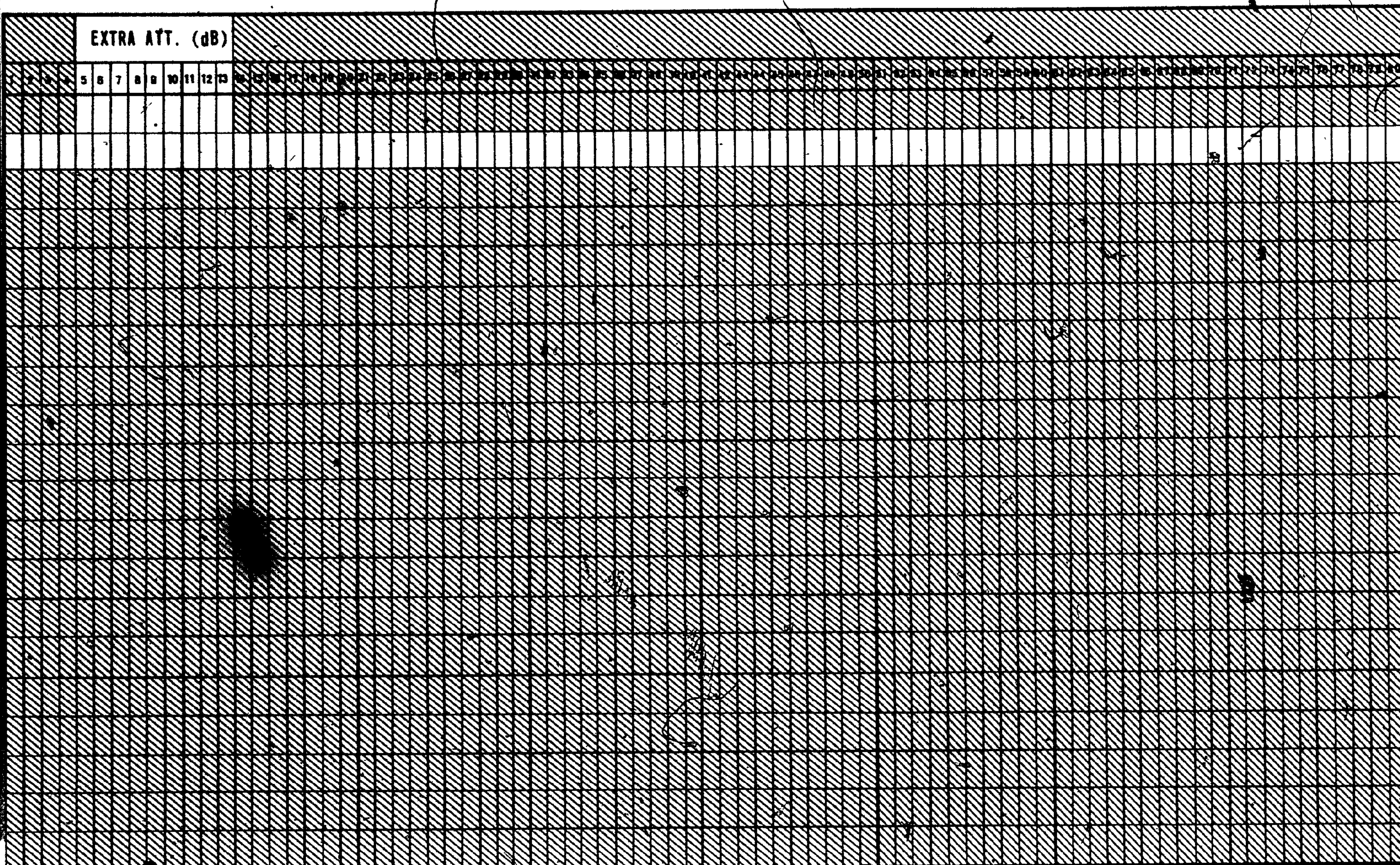


FIG. 4 - FORMAT (1x, 2(3x, F9.4), T70, I3)

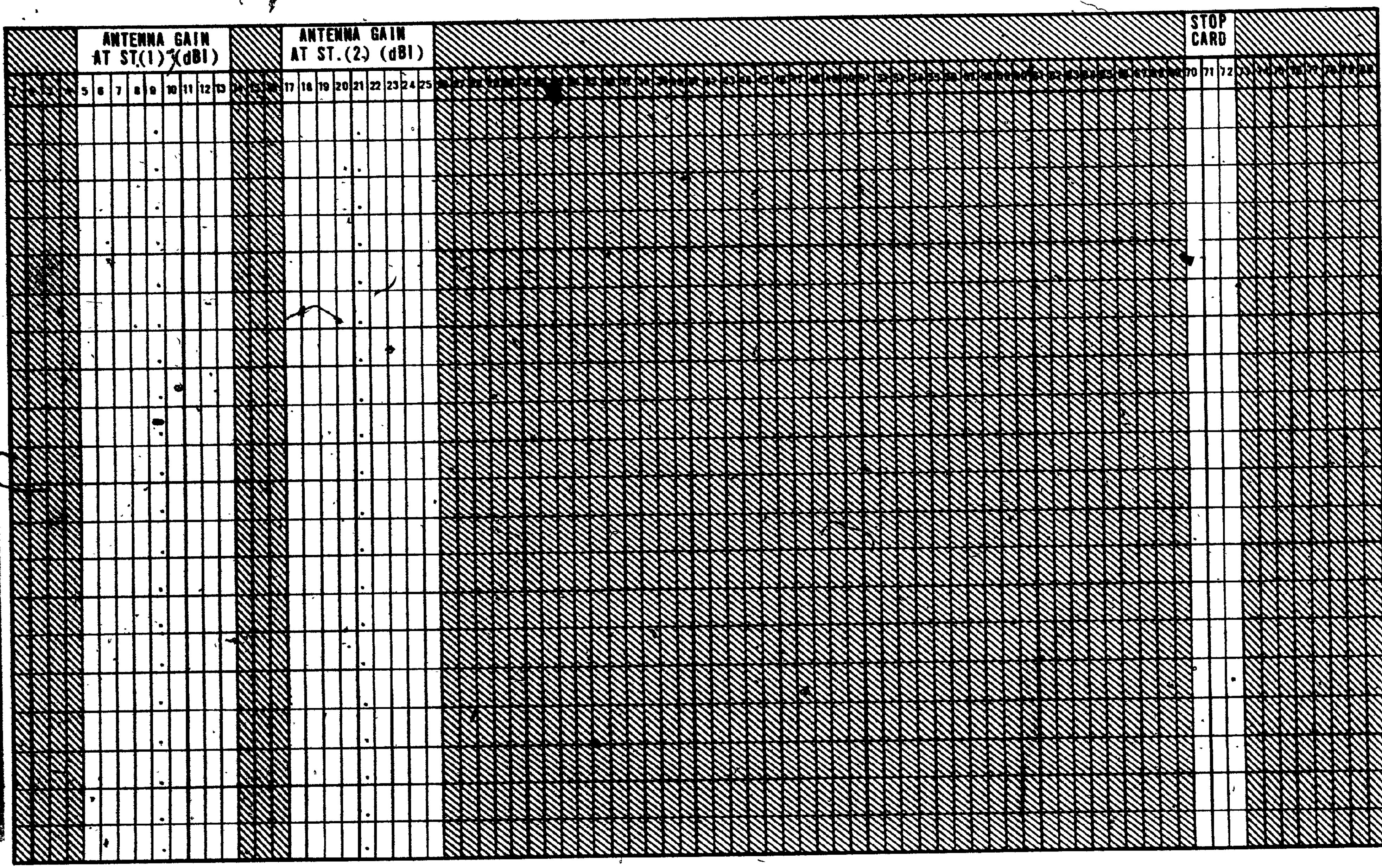


FIG. 5 – DATA CARDS FOR THE ENCLOSED EXAMPLE

Columns 1–10	Columns 11–24	Columns 25–34	Columns 35–46	Columns 47–60	Columns 61–75	CARD NUMBER
16.9	.925					1
4.	.5					2
38.8	38.8					3
1.9	1.9					4
200.0	200.0					5
2.0	2.0					6
1.0	1.0					7
-89.0	9.0					8
2700.8	124.0	35.0	24.0	35.0		9
4.1						10
						11
22.0	22.0					12
28.0	28.0					13
33.0	33.0					14
36.5	36.5					15
40.0	40.0					16
42.5	42.5				999	17